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Analysis of Economic Effects of Environmental Regulations on the Integrated Iron and Steel Industry. Volume II

Temple, Barker and Sloane, Inc., Wellesley Hills, Mass.

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An analysis of the economic impact of environmental regulations on the Integrated Iron and Steel Industry. The most likely impact in terms of capital expenditures will be $6.8 billion for 1975 through 1983. Of this, $3.6 billion will be required for water and $3.2 billion will be required for air pollution control. Annual operating costs should increase less than 2 percent during the next decade. The increase to steel users will be less than 5 percent.

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PTm(Steel) performs similar calculations for all years in the period from 1955 to 1972 and for all steel industry processes. At the conclusion of these calculations the model has developed a series of depreciation charges for each year from 1973 to 1990 attributable to the initial investment in fixed assets for each process.

CONCLUSION

The total depreciation flows attributable to the production equipment in place in 1972 are equal to the sum of the three increments discussed above. Given the limitations of the data provided to TBS, the methods described result in a reasonably accurate computation of depreciation. More accuracy could be obtained only by gathering extremely detailed data on the timing and magnitude of expenditures on fixed assets over the past two decades. Much of this information would be viewed as proprietary by the companies involved.

ANALYSIS OF ECONOMIC EFFECTS OF ENVIRONMENTAL REGULATIONS ON THE

INTEGRATED IRON AND STEEL INDUSTRY

Volume II

Prepared for:

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PLANNING AND EVALUATION

by:

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JULY 1977

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This report has been reviewed by Temple, Barker & Sloane, Inc. (TBS) and EPA, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

PREFACE

This report is the result of a major program of studies sponsored by the Environmental Protection Agency as part of its continuing effort to assess the economic impacts of its regulatory programs. Unlike many of EPA's other industry economic studies where the focus is on the impact of a particular regulation, this study was aimed at examining the combined effect of all of EPA's direct regulatory programs on the integrated iron and steel industry. This was an ambitious objective and in some instances it was not possible to take every regulation into account due to the lack of data or the absence of final regulations; however, it was possible to focus quantitatively on the most significant programs, primarily those dealing with air and water pollution control.

In addition to providing an assessment of the combined impact of EPA's regulatory programs, a major objective of this study was to advance the methodologies used in previous studies so as to provide more accurate conclusions as well as provide a better foundation for future studies. This was done in many cases by making use of more up-to-date or previously unused data in areas such as industry production cost and pollution control cost. However, advances also may have been made in the basic analytical techniques used for impact analysis.

In sponsoring this study the EPA wanted to make an independent assessment of the integrated iron and steel industry. Although the overall conclusions are endorsed by the Agency, there may be instances in which technical judgments of the contractor differ from those of the EPA. Similarly, assumptions used in the study that are of a policy nature should not be construed as an indication of EPA policy intentions.

This report was prepared for EPA by Temple, Barker & Sloane, Inc. of Wellesley Hills, Massachusetts, under contract number 68-01-2832. Additional copies are available through the National Technical Information Service, Springfield, Virginia 22151. Further information concerning this and other economic studies conducted by EPA can be obtained through the Office of Planning and Evaluation, U.S. Environmental Protection Agency.

ACKNOWLEDGMENTS

A study of this complexity cannot be undertaken without the cooperation of many individuals. From the outset, Temple, Barker & Sloane, Inc. (TBS) worked closely with a committee of top level industry executives organized by Dr. S. Fletcher of the American Iron and Steel Institute (AISI). This AISI committee was chaired by Mr. W. Lowe of Inland Steel and included Messrs. F. Armour of Interlake, Inc., D. Brewster of Inland Steel, J. Lowey of Republic Steel, and E. Mallick and B. D. Smith of United States Steel (USS). TBS would like to express its appreciation for the contribution made by the members of this committee.

A number of other steel industry representatives also contributed to this study. Mr. B. D. Smith of USS and his staff, including Messrs. W. Renner, R. Ganem, L. Van der Veer and A. Skirboll, were particularly helpful. Throughout the TBS study, these USS representatives provided valuable industry perspective and insightful comments. We would like to offer our special thanks to Mr. R. Ganem. Messrs. D. Hawley of Inland Steel and A. Monnett of USS provided TBS with valuable assistance in the area of forecasting domestic steel shipments. In addition to Dr. Fletcher, other staff of the AISI making contributions include Messrs. F. Langenberg, J. Collins, E. Sommer, and K. Allen.

The TBS study utilized detailed industry operating data collected by Arthur D. Little for the AISI. Interpretation of these data was provided by Messrs. S. Margolin, K. Parmeswaran, T. Rothermel and J. Stevens.

Individuals from several organizations assisted in developing the detailed cost equations for pollution control equipment. Among these were Messrs. T. Centi and J. Boros of NUS/Cyrus Rice Division, P. Beltz and J. Varga of Battelle Columbus Laboratory, J. O'Connor and R. Jenkins of the Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards, and E. Hall, W. Hunt, E. Dulaney, J. Williams and P. Williams of the EPA's Effluent Guidelines Division.

EPA's Office of Planning and Evaluation provided direction throughout this project. Messrs. A. Brueckmann, S. Besse and J. Kamihachi guided TBS' effort, providing perspective, assisting in data collection, and undertaking more than their fair share of the unpleasant tasks associated with a project of this scope. Messrs. A. Alm, P. Brands and R. Gamse offered valuable comments and encouragement.

TBS' staff was augmented during the study by several key professionals from other organizations. Professor S. Bradley of the Harvard Business School assisted in the development of PTm(Steel), a computer-based model of the steel industry. Professor J. Light of the Harvard Business School developed TBS' analysis of capital market conditions in the past and the projections of future conditions. Mr. A. Steinburgh of Resource Planning Associates assisted in the initial stages of the project.

Valuable comments on an early draft of this report were received from: Messrs. B. D. Smith, D. Dilley and R. Ganem of USS; J. Briggs and R. Woodward of Bethlehem Steel; W. Sullivan of the Department of Commerce; R. Crandall and R. Greene of the Council on Wage and Price Stability; and D. Brazell of the Council of Economic Advisors.

While pleased to acknowledge all the assistance it has received during this study, TBS of course takes full responsibility for the study's analysis and conclusions.

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1. INTRODUCTION

Volume II of this report describes the research methodology employed in the study of Economic Impact of Environmental Regulations on the Iron and Steel Industry by Temple, Barker & Sloane, Inc. (TBS). All results of the analysis are contained in Volume I.

end

It is anticipated that Volume II will provide knowledgeable researchers with sufficient information to verify all computations performed in this analysis.[1] To accomplish this objective, a tremendous amount of data and detailed explanation has been included in this volume. The reader with only general interest in the methodology may be satisfied with the overview presented in Section 9 of Volume I or may review the text of this volume without reference to supporting exhibits and examples.

RESEARCH METHODOLOGY

In order to deal with the complex and interactive elements of the steel industry and those environmental regulations which affect the industry, TBS employed a computer model of the steel industry. This model, PTm(Steel), is one of a series of Policy Testing models developed by TBS for different industries. PTm(Steel) embodies the structural relationships among processes, flows, capital and regulatory requirements, but is independent of assumptions about exogenous conditions such as demand or interest rate and behavior such as capital structure. All such assumptions are specified by the user and may be varied to test the sensitivity of policy decisions to them.

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[1] *We are indebted to Dr. Barry Bosworth of the Brookings Institute who performed just such a task using an early draft of Volume II.*

PTm(Steel) has three main components: production, pollution control, and finance. Production includes determination of production flows by process and resulting capacity needs. From these, production operations and maintenance costs are computed. The pollution control component is separated into water and air modules. Each module relies upon production and capacity data determined by the production component and upon detailed pollution control engineering cost estimates in computing the costs of pollution control. The finance component combines these costs and capital needs to display the results of operations in terms of capital expenditures, external financing, operations and maintenance expenses, required revenues and average price effects.

Policy analysis is performed with PTm(Steel) by incremental analysis. A baseline or reference case representing a set of cost data and assumptions is established. Subsequent analyses vary one or more conditions or assumptions to determine the "incremental" effect.

In Volume II, as in other parts of this report, the data presented represent 93 percent of domestic steel shipments. This definition is necessary in order to effectively utilize the most detailed and accurate production, capital, and process inventory data available. The American Iron and Steel Institute (AISI), whose members operate 139 plants, provided 1972 operating data for 130 of these plants from a recent study.[2] These respondents represent 99 percent[3] of AISI member shipments. AISI members represent 94 percent[4] of total domestic shipments so that the study data includes facilities which account for 93 percent (99 percent x 94 percent) of total domestic shipments. All data relating to units of production and most financial data can be expanded from the steel industry as used in this study to total domestic shipments by using the conversion factor of 1.075 (1 ÷ 0.93). However, extrapolation to total steel company operations which include raw materials and non-steel businesses should not be attempted.

This analysis includes shipments and production of carbon, alloy, and stainless steel. Frequently, these different grades are all produced in the same facilities. Therefore, the additional costs incurred in producing these alloy and stainless products are included in the total cost of operating each facility.[5] Since the relative amounts of alloy and stainless have remained in stable proportion for several years, extrapolation of total plant costs to new volume levels accurately includes the cost of alloy and stainless production.

Costs and impacts in this analysis include only those iron and steel industry operations from receipt of raw materials at the blast furnace or coke oven site through the finishing mills. All costs of raw material mining, preparation, and transportation are excluded except as they are included in the cost of raw materials used. Also, all subsequent

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[2] *"Steel and the Environment: A Cost Impact Analysis," by Arthur D. Little for AISI, May 1975, p. I-2.*

[3] *Ibid., p. I-2*

[4] *Ibid., p. I-1*

[5] *Pollution control costs for special treatment of alloy and stainless products were not included in this study.*

fabrication of steel products and non-steel operations has been omitted. The production system diagram in Exhibit 1 illustrates the processes included in this analysis.

GUIDE TO VOLUME II

Volume II is organized in accordance with the major components of the analysis. Thus, the sections are:

- Introduction
- Production Costs
- Water Pollution Control Costs
- Air Pollution Control Costs
- Finance Analysis Methodology
- Appendix A--Steel Demand
- Appendix B--Reinvestment Rates and Depreciation Calculations

The order of presentation is as listed since the middle two are dependent upon data from the first component, and the final component, finance, is dependent upon data from each of the others.

2. PRODUCTION COSTS

METHODOLOGY OVERVIEW

Analysis of the economic impact of pollution abatement regulations upon the steel industry has been performed with the aid of a computer model, PTm(Steel). Determination of production costs requires the six steps below:

- Total steel shipments
- Product category shipments
- Production requirements
- Capacity requirements
- Capital expenditures
- Production operations and maintenance costs

Total steel shipments are specified by the analyst. PTm(Steel) does not forecast shipments but analyzes alternative estimates of shipments. Thus, it is possible to simulate planning uncertainties by comparing results of different levels of total steel shipments for planning facilities and for shipments.

Product category shipments are derived from total steel shipments. The proportion of each product category, or product mix, is estimated for each year and multiplied by total shipments to obtain shipments in each product category. The basis for this analysis is an extrapolation of historic trends. Other estimates such as a constant mix or selected hypothetical mix could also be analyzed. The 12 product categories used in this study are shown in

Exhibit 2 along with their relationship to product categories contained in the AISI annual Statistical Report.[1] These categories were selected for their capability to represent market behavior, for their clear relationship to production processes, and for the availability of both market and production data related to these categories.

Production requirements are determined from shipments of each product. The production system used in this analysis is presented schematically in Exhibit 1. The system consists of 28 steelmaking, forming, and finishing processes plus ancillary facilities such as power generation. Each product follows a unique and ordered path through several of the processes. Thus, production for each process may vary with total shipments or a change in the product mix. Therefore, production cannot be viewed in aggregate, but must be considered for each process. Production for each process is determined by totaling the production requirements for that process by each of the 12 product categories. Production requirements are also affected by consideration of alternative processes which produce substitutable semi-finished products such as continuous casting or conventional casting and primary breaking. The yield or processing loss through each process must also be considered. The yields for each process are listed in Exhibit 3. Production requirements per ton of shipments for each process of each product are presented for selected years in Exhibit 4.

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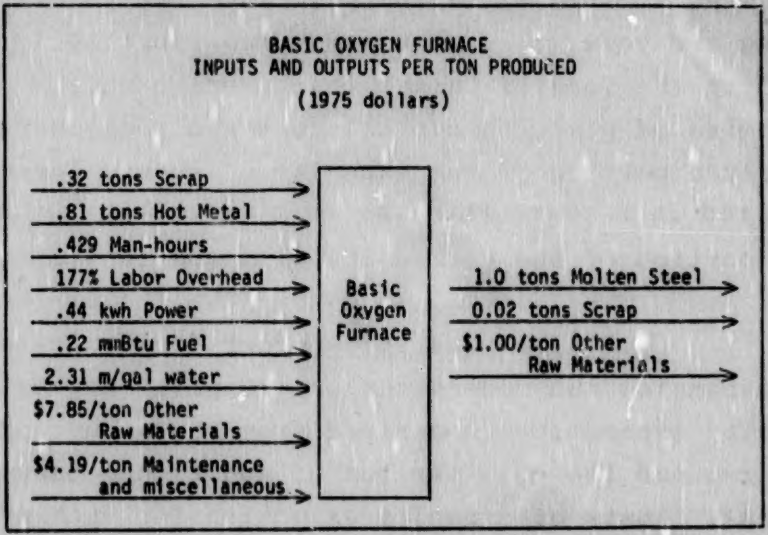
[1] *The 12 product categories used in this analysis are the same as those used in the Arthur D. Little study for AISI, "Steel and the Environment: A Cost Impact Analysis."*

Capacity requirements are determined from production requirements and consideration of an adequate reserve for maintenance downtime and production flexibility. This reserve is reflected in the planning utilizations in Exhibit 5. These factors for each process are the maximum utilization of capacity which can be sustained over the long term. The capacity requirement for any process is the amount which, when multiplied by the corresponding planning utilization, equals the production required for that process.

When the capacity requirement exceeds available capacity, additional capacity is added. Capacity is added during the year it is required. New capacity is always added in the form of larger than average units which offer economies of scale in capital cost and some operating costs. If only a portion of the capacity of such a large unit is required in a year, then the unit is brought on stream for only that portion of the year which will add the capacity required.

Capital expenditures occur for two reasons, capacity expansion and modernization. Capital expenditures for capacity expansion are derived from the amount of expansion required and the cost per ton of additional capacity for the process. Costs of capacity expansion for each process are listed in Exhibit 6. Capital expenditures for modernization are calculated as a percent of the replacement cost of facilities. A different modernization rate may be used for each process. The modernization rates employed in this analysis are contained in Exhibit 7.

Production operations and maintenance costs are computed from the price of each production resource used times the amount of each production resource required. The production resources required for each process are determined from the production required and the amount of resources required per ton of production. Exhibit 8 is a table which contains the resources required to produce one ton for each process. The diagram below describes the flow of production resources through a large basic oxygen furnace (BOF).


BASIC OXYGEN FURNACE
INPUTS AND OUTPUTS PER TON PRODUCED
(1975 dollars)

.32 tons Scrap
.81 tons Hot Metal
.429 Man-hours
177% Labor Overhead
.44 kwh Power
.22 mmBtu Fuel
2.31 m/gal water
$7.85/ton Other Raw Materials
$4.19/ton Maintenance and miscellaneous
Basic Oxygen Furnace
1.0 tons Molten Steel
0.02 tons Scrap
$1.00/ton Other Raw Materials

From the example above, one ton of production in the basic oxygen furnace can be seen to require .32 tons of scrap and .81 tons of hot metal, among other things. In addition to one ton of steel output, .02 tons of scrap and $1.00 of mixed quantities of "other raw materials" are also generated. The price of each resource can be determined for selected years from Exhibit 9. In 1977, scrap price is

$100.72 per ton, so that scrap used in the BOF would contribute $32.23 to production operations and maintenance costs for each ton of BOF production.

DATA SOURCES

Data on production, costs, and technology were gathered from a variety of sources. However, most of the data related to production and inventory of process units were obtained from the AISI as a result of an independent analysis of the steel industry performed for AISI by Arthur D. Little (ADL).[2]

The data required for TBS' analysis were not a part of the published ADL report. The data were provided under a subcontract with ADL with concurrence from AISI in response to a specific request by TBS.

Though ADL collected data on specific plants, it was necessary to aggregate these data into groups which consisted of similar facilities in terms of age and size in order to avoid disclosure of proprietary data on individual firms or processes. Each group had to include at least three units to meet this limitation.

The request had three parts. The first part was an inventory of facilities in the steel industry in 1972. For each group of each process, the number of facilities, capacity,

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[2] *"Steel and the Environment: A Cost Impact Analysis," by Arthur D. Little for AISI, May, 1975.*

production, 1972 replacement value, and depreciated replacement value were provided. The second part of the request was for resources required and credits obtained to produce one ton of output for each process. The third part requested cost information on resource requirements and details of labor and overhead requirements by size of facility. Labor and overhead were separated by size of facility as these are the only resources which were found to exhibit economies of scale.

In order to obtain costs of resources used in future years, the 1975 price is multiplied by the anticipated cost escalation factor. Exhibit 9 contains the 1975 prices for eight cost items used in this analysis. Additional resources were priced in terms of dollars per ton of output from the process rather than per unit of the resource since their composition was too varied to select a unit for pricing. Cost escalation factors for each item for representative years are contained in Exhibit 10. The factors represent actual increases for 1973 and 1974 where available.

From the exhibits described above, the price of iron ore in 1977 can be determined by multiplying the 1975 price per ton of $23.09 times the 1977 inflation factor of 1.183 to obtain $27.31 per hour. Some resources such as chemicals are input to the model as dollars per ton of output for each process. The cost of such items in any year is determined by multiplying the cost per ton from Exhibit 8 times the corresponding cost escalation factor for the year.

The procedure described above has been utilized to determine prices for selected future years in Exhibit 9. The cost escalation factors were determined from a variety of sources. Each source is noted in Exhibit 10.

To convert current dollar expenditures to constant 1975 dollars, it is only necessary to correct for the changed value of the dollar. Thus, all items in current dollars of a year are converted to 1975 dollars by the same factor. The procedure is described below:

Price of item j in year i = Price in year i in current dollars ÷ GNP inflation factor

For example, the cost of iron ore in 1977 current dollars was calculated above to be $27.31 per ton. This can be converted to 1975 dollars as shown below:

Price in 1977 of iron ore	$27.31
GNP escalation to 1977	1.140
Price of 1977 labor hours in 1975 constant dollars	$23.96

For resources where cost escalation is different than GNP inflation, the 1975 constant dollar price for resources expended in future years would not be the same as the 1975 current dollar cost.

TOTAL STEEL SHIPMENTS

Analysis with PTm(Steel) begins after the specification of total demand. The level of operations within the steel industry is directly related to domestic shipments of steel products rather than steel demand, which is usually assumed to be apparent consumption and includes imports and inventory changes. Therefore, shipments is the measure used within PTm(Steel). Operation of the model requires input of total shipments of steel products for each year of analysis. Thus, the impact of a variety of assumptions regarding the future level of steel shipments can be determined.

In order to develop the baseline schedule of steel shipments, TBS examined the forecasts of many different sources. These forecasts were grouped according to the methodology employed; and estimates of steel consumption, net imports, and shipments were compared for the years through 1985. Methodologies examined ranged from simple trend extrapolation to complex econometric models. The full report of this work is contained in Appendix A. Analysis of the different forecasts shows that, with the exception of a small number of unrealistically optimistic or pessimistic forecasts, all predictions were within plus or minus 10 percent of the long-term trend in steel shipments.

Although steel shipments have been cyclical historically, TBS has used an extrapolation of the 1960-1974 linear trend as the baseline shipments schedule.[3] The linear trend and the 1960-1974 actual shipments data are displayed in Exhibit 11 along with the shipments of 93 percent of the industry used in this analysis.

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[3] *AISI Annual Statistical Reports. The specific trend used as the reference point was based on a least-squares linear trend line fitted to actual shipments data from 1960 to 1974.*

There are five reasons for this choice. First, as mentioned above, the linear trend provides an approximate median for the larger group of forecasts examined. Second, in an analysis such as this which spans nearly a decade, cycles in demand as well as in other economic variables can be expected to compensate each other. Thus, a trend line is an adequate representation of the average demand over time. Third, much of the cyclical effect observed in steel shipments is due to inventory changes by steel users. Since these do not affect eventual consumption, elimination of these inventory changes results in shipments which are closer to actual consumption. Fourth, the linear trend methodology is simple to explain and does not rely on difficult or controversial forecasting methods. Finally, conversations with industry officials and other knowledgeable individuals indicated that trend extrapolation is actually used by the industry to provide a long-term planning base for capital decisions.

PRODUCT CATEGORY SHIPMENTS

Total steel shipments are allocated to the 12 product categories in each year. Shifts between product groups, even at a constant level of total shipments, can result in significant changes in production by process. The allocation of total shipments to products in each year is an input to PTm(Steel) and could be developed in a number of ways. For the purposes of this analysis, TBS has developed and compared two methods of product allocation.

The first and simplest method considered allocates steel shipments to products assuming that the same product mix will prevail in all future years. For this option actual product mix was used for 1972, 1973, and 1974[4] and the 1972 mix was then used for the years 1975 to 1985.

The second method considered by TBS allocates shipments to products based on the trend in each product's share of total shipments from 1960 to 1974. This was determined by developing, for each product, linear regression equations which related total shipments of each product with an independent variable such as time, real GNP, or total steel shipments. The statistical characteristics of these equations were compared, and the one with the best fit to the data was used to predict individual product shipments. In all but one case, equations using total steel shipments as the independent variable were used. However, for direct shipments of semi-finished goods (Product category 1) time was used as the independent variable. For each future year, individual product demands were summed, and then the percent share for each product was developed. Again actual product mix was used for 1972, 1973, and 1974, and the resulting "trended" case is shown in Exhibit 12.

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[4] *AISI Annual Statistical Reports.*

Other equally valid methods of forecasting product mix could be developed and input to PTm(Steel). For the purposes of this analysis, however, the trended product mix was used in the baseline analysis of the industry, and the sensitivity of the results to the alternative static mix was examined. This choice was made because the trended mix better described both the historical product mix data and the future changes in product mix expected by the industry.

PRODUCTION REQUIREMENTS

The schematic in Exhibit 1, which represents the steel production system, characterizes steelmaking as a flow network. This characteristic has been employed to calculate the production requirements for each process. The input/output network is a convenient way to account for flows of multiple resources through alternative processes to become multiple products.

The network is defined by the paths which intermediate products move along from process to process. Galvanized sheet and strip, for example, arrives as cold rolled strip at the galvanizing mill from the cold rolled strip mill. The input used by the cold rolled strip mill is pickled hot strip from the hot rolled strip mill via pickling and oiling. The input used by the hot rolled strip mill is slabs which may have come from either a continuous slab caster or a primary slab breaking mill. Slabs from a breaking mill were first cast as ingots. Whether cast continuously or as ingots, the molten steel used came from one of three types of furnaces: open hearth, basic oxygen, or electric. These furnaces were each fed by a mixture of scrap and molten iron. The molten iron from the blast furnace requires several raw materials which each require preliminary processing. A similar flow exists for each product. Each such path, with its alternatives, can be constructed from the flow network shown in Exhibit 1.

Most processing steps result in some material loss. More input is required than output is received. The ratio of output to input is the yield for the process. Yields for each of the 28 steelmaking processes are contained in Exhibit 3. Since the yield for the galvanizing mill is 0.962 tons out per ton in, in order to ship one ton of galvanized sheet or strip, 1.04 tons (1.0 ton ÷ 0.962 yield of cold rolled strip) will be required. This procedure is repeated for each process required to produce galvanized product until the production requirement for each process is determined.

Exhibit 4 shows that shipment of one ton of galvanized sheet and strip in 1972 and in 1977 requires the production by process tabulated on the following page.

Technology shifts between alternative processes can be observed in this example. The production requirement for total slabs remains constant at 1.32 tons of slabs per ton of galvanized sheet and strip. However, the relative amount of slabs provided by continuous casting increases. Due to the better yield obtained through continuous casting, the requirement for molten steel is reduced. Among the three steelmaking furnaces, the relative mix also changes as BOF and electric replace open hearth.

PRODUCTION REQUIREMENTS
FOR ONE TON OF GALVANIZED SHEET AND STRIP

Process	Tons Of Production Required			
		1972		1977
Hot Coating - Galvanizing		1.00		1.00
Cold Rolled Strip		1.04		1.04
Pickling and Oiling		1.19		1.19
Hot Rolled Strip		1.26		1.26
Primary Breaking - Slabs	1.23		1.15	
Continuous Cast - Slabs	.09		.17	
Slabs - TOTAL		1.32		1.32
Conventional Cast Ingots		1.47		1.38
Open Hearth Furnace	.42		.32	
Basic Oxygen Furnace	.90		.95	
Electric Furnace	.28		.32	
Molten Steel		1.60		1.59
Blast Furnace Iron		.99		.98
Coke		.57		.55
Sinter		.35		.34
Scrap		.82		.82
Coal		.81		.80
Ore and Pellets*		1.57		1.54

**Includes feed to sinter strand.*

As stated above, total production requirements for each process are the sum of the requirements for each product. Exhibit 13 uses the procedure described above for each product to determine the production requirements for each process in order to produce 1,000,000 tons of total output. This output is allocated to products according to the 1972 mix of products and using the 1972 mix of alternative processes.

TECHNOLOGY CHANGES

The relative amount of semi-finished steel produced by alternative processes is not constant. The alternatives represent different technologies, where one process is replacing the other or where capacity additions will tend toward the newest technology.

There are three technology processes where significant shifts in production technology will occur over the next decade. These are casting and primary breaking, steelmaking furnaces and vacuum degassing. The percent produced by each technology is shown in Exhibit 14. The total production of slabs in 1972 was made up of 7 percent from continuous casting and 93 percent from primary breaking. By 1983 these ratios will change to 24 percent from continuous casting and 76 percent from primary breaking.

These shifts are built into the analyses in different ways. The shift among steelmaking furnaces is accomplished by specifying the percent of production which must come from each type of furnace. It is assumed that many open hearth furnaces will be retired or underutilized with the shift to basic oxygen and electric arc furnaces. The increase in vacuum degassing occurs as production shifts to more modern steelmaking furnaces. It is assumed that 33 percent of basic oxygen furnace and 40 percent of electric arc production are vacuum degassed.[5]

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[5] *Estimates by NUS/Cyrus Rice engineering staff.*

Increases in continuous casting occur since it is assumed no new breaking mills will be added and that the shift to continuous casting will exceed a prespecified minimum share of production.[6]

PRODUCTION REQUIREMENTS BY FACILITY

The production required from each process is derived from different size units. Production is allocated to each unit such that utilization will be the same, regardless of age or size. The method is explained in detail below.

CAPACITY REQUIREMENTS

PROCESS UNIT INVENTORY

The inventory of steel production units in place in 1972 used in this analysis was based upon a study of AISI member plants by Arthur D. Little. Units of each process were divided into groups with similar characteristics of age, size, and location. Data within each group were averaged to define several "typical" units for each process. For example, the data on the following page were obtained for basic oxygen furnaces:

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[6] *The minimum specified share is the share obtained as shown in Exhibit 14.*

BASIC OXYGEN FURNACES
INVENTORY
1972

	Size	
Age	Small	Large
Pre-1946	none	none
1946-1972		
- Number of units	16	16
- Total Capacity (millions of tons)	25.73	60.54

The capacity of a "typical" small basic oxygen furnace is therefore 1.61 million tons per year (25.73 million tons per year ÷ 16 units). A "typical" large unit is 3.78 million tons per year.

The data obtained from ADL regarding 1972 capacity have been summarized in several exhibits. Exhibit 15 contains the number of plants in each size and age group. Exhibit 16 contains the capacities of all units in each size and age group. Finally, using the procedure described above, the size of "typical" units for each size and age group is tabulated in Exhibit 17.

The amount of detail available regarding size and age was limited in order to avoid disclosure of proprietary data. Therefore, some processes may have fewer size or age groups. This method has provided a profile of facilities represented by typical units made up from groups of units which are homogeneous.

Some studies have argued that actual individual facilities must be used. There is no doubt that such an approach would be preferable to use of one typical unit to represent all units in a process or worse, all units in several different but related processes. However, several typical units for each process provide a reasonable representation of actual facilities. Even with a plant specific approach, future facilities have to be represented by similar "typical" plants. Furthermore, extrapolation of the existing production system into the future can be very misleading since the mix of products and facilities will probably change. In any event, plant specific data are not available, and the data used in this study are the most detailed, recent, and accurate data available in the public domain. Most importantly, though, the AISI study of 130 plants found no significant variance in resource use by size or age except for labor and overhead.[7] In the case of labor and overhead, data for the three typical process units provided by Arthur D. Little approximate the non-linear relationship between size and these resources.

CALCULATION OF CAPACITY REQUIREMENTS

Capacity requirements are determined from production requirements and a reserve for maintenance downtime and production flexibility. The procedure for determination of production requirements was described above. The reserve is embedded in the planning utilization. The planning utilizations listed for each process in Exhibit 5 represent the average percent of capacity which can be utilized for long periods of sustained production.

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[7] *Project manager, Arthur D. Little.*

The planning utilizations listed in Exhibit 5 were obtained from the AISI.[8] They represent informed industry opinion regarding normal operating practices. Generally, steel finishing operations have the lowest planning utilizations. This is necessary to provide the flexibility required to meet short-run changes in product mix. Iron and steelmaking operations run at 90 percent, which implies operations at 100 percent of capacity, except for maintenance downtime[9] and some limited production flexibility. Primary breaking and hot strip operations are the bridge between steelmaking and steel finishing and thus have planning utilizations slightly lower than the maximum.

No capacity additions are forecast for open hearth furnaces, ingot casting or any of the primary breaking mills because of the anticipated shift to competing technologies. As described in the previous section, production of products from these mills is shifted to the newer, competing technologies.

Capacity requirements in any year are the amount necessary to produce the production requirement after reduction by the corresponding planning utilization. This capacity requirement is then compared to the available capacity which includes the 1972 inventory and all additions between 1972 and the year considered. Thus, if production requirements for the basic oxygen furnace in 1977 were 80.0 million tons, capacity requirements would be 88.89 (80.0 ÷ 90) million tons.

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[8] *AISI Advisory Committee discussions with TBS.*

[9] *For example, Bureau of Mines data indicate that at any given time about 5 to 10 percent of blast furnaces are down for maintenance (Annual Statistical Report, 1964-1974).*

If no capacity had been added from 1972 through 1976, available capacity would be 86.27.[10] The requirements for additional capacity would be 2.62 million tons (88.89 - 86.27).

Production requirements are determined so that the utilization of all typical facilities is the same. Continuing the example above, the following table illustrates how capacity requirements are determined and how production requirements are assigned to facilities.

BASIC OXYGEN FURNACE
CAPACITY AND PRODUCTION REQUIREMENTS
(millions of tons)

	Small	Large	Total
1972 Capacity	25.73	60.54	86.27
Additions 1972-1976	0	0	0
1976 Capacity	25.73	60.54	86.27
1977			
Production Requirements			80.00
Capacity Requirement			88.89
Capacity Addition	0	2.62	2.62
Capacity	25.73	63.16	88.89
Utilization (ratio)	.90	.90	.90
Production by size	23.16	56.84	

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[10] *Exhibit 16.*

Additions to capacity are placed in service in the year required. This assumes that steel firms are planning to meet the apparent trend in steel shipments. Additional capacity is in the form of large units. However, only the amount of capacity required during a year is added. To accomplish this, units may be added part-way through the year and be expressed as a fractional unit.

No additions to capacity occur in this analysis during 1973 and 1974. This limitation is necessary due to the lack of available data on actual capacity additions. The great increases in production during this period were accomplished by operating some mills above their rated capacity. Downtime necessary to install new productive units and even some maintenance may have been postponed to achieve these high rates of production.

CAPITAL EXPENDITURES

Capital expenditures for productive capacity occur either because of additions to capacity or modernization of existing facilities.

CAPITAL EXPENDITURES FOR CAPACITY ADDITIONS

Capacity additions are assumed to be in the form of large efficient units. All additions to a process in a year cost the same per ton. The 1975 cost per ton for each production process is contained in Exhibit 6. For example, additional basic oxygen furnace capacity costs $25 per ton in 1975. Due to anticipated cost escalation, this will increase to $28.84 per ton in 1977 in current dollars.[11]

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[11] *Exhibit 10, ($25.00 x 1.154).*

The costs contained in Exhibit 6 are for round out of existing capacity--that is, addition of processes at existing sites. When it becomes necessary to construct new facilities on greenfield sites, costs are greater due to the need for support facilities.[12] Costs of greenfield units are 28 percent higher than for round out. Production facilities will be in balance once utilization of all casting reaches its planning level. Construction of any process after that time is based on greenfield costs.

The total cost for additions to a process in a year is the cost per ton times the number of tons of capacity added. The total for the steel industry is then the sum of expenditures for each process.

Construction of capacity additions is expected to require four years from initial expenditure to in-service date. Therefore, the total cost of each capacity addition is incurred partially in each of the four years before the unit is in service. Since facilities might be completed at any time during the year, they are assumed to be completed on average at mid-year, so a four-year period actually causes expenditures in five calendar years. The total expenditure is spread to each year according to the following pattern:

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[12] *Round out occurs until industry steelmaking and finishing facilities are in balance. Thereafter, bare sites for "greenfield" construction are necessary.*

CONSTRUCTION EXPENDITURES BY YEAR

	--------Percent Expended----------	
YEAR	Calendar Year	Years Prior to Actual Completion
Placed in service	10%	25%
1 Year prior	30%	30%
2 Years prior	30%	25%
3 Years prior	20%	20%
4 Years prior	10%	0%

The basic oxygen furnace built in 1977 as described above with a 2.62 million ton annual capacity (and cost of $28.84) per ton would result in the following capital expenditures:

BASIC OXYGEN FURNACE
CAPITAL EXPENDITURES
(1977 current dollars)

Capacity (million tons)	$ 2.62
1977 Price per Ton	28.84
1977 Total Cost (millions)	$75.56

The total cost of $75.56 million would be spread to five calendar years as shown below:

BASIC OXYGEN FURNACES
CAPITAL EXPENDITURES BY YEAR
(millions of current dollars)

1977	$ 7.56
1976	22.67
1975	22.67
1974	15.11
1973	7.56
Total	$75.56

The expenditures in current dollars of each year totals the current dollar cost in 1977. These expenditures are converted to 1975 constant dollars in the table below.

BASIC OXYGEN FURNACE
CAPITAL EXPENDITURES BY YEAR
(millions of 1975 dollars)

1977	$ 6.63
1976	21.17
1975	22.67
1974	16.54
1973	9.12
Total	$76.13

The resulting cost in constant 1975 dollars of $76.1 million is greater than the current dollar total or $75.6 million because part of the expenditure was incurred in dollars of higher value in earlier years. Notice that dollars spent in 1973 and 1974 have higher constant dollar value than their current dollar value. This procedure must be followed in obtaining constant dollar values for capital expenditures, since it recognizes the timing of the expenditures. Simply converting the entire cost of $75.6 million to 1975 constant dollars results in a value of $66.3 million. However, this is incorrect as it ignores the actual timing of expenditures.

MODERNIZATION

Expenditures for modernization are a function of the value of facilities installed. The annual expenditures for modernization are determined by multiplying a factor for each process times the current replacement value of units in that process. The factors used in this analysis are listed in Exhibit 7. They were derived from historical data from AISI member facilities provided to TBS by Arthur D. Little. A technical description of their derivation is contained in Appendix B.

Again using the example of a 2.62 million ton basic oxygen furnace completed in 1977, average annual modernization expenditures would be computed as shown below:

BASIC OXYGEN FURNACE
MODERNIZATION EXPENDITURES IN 1980
Size: 2,620,000 tons
(current dollars)

Initial cost in 1977 (millions)	$75.56
1980 Replacement cost (millions)	$89.15
Modernization rate	.01
Annual modernization cost in 1980 (millions)	$ .891

Using Exhibit 10 to compute the replacement cost in each year, the annual modernization cost for the basic oxygen furnace can be determined for selected years as on the following page.

While the new basic oxygen furnace described on the following page may not incur any modernization cost in the first years, at a future year it may incur a much greater cost than the annual contribution in that year. The annual modernization expense is an accrual which is used as needed and may be spent in a particular year on any unit or, in some years, not at all. Costs of modernization are incurred in each year. Therefore, they are not allocated to prior years as in the case of expenditures for capacity additions.

BASIC OXYGEN FURNACE
ANNUAL MODERNIZATION COST
(millions of current dollars)

1977	$ .756
1980	$ .891
1983	$1.033
1985	$1.150

Modernization costs are frequently difficult to separate from capacity expansion costs in historical data. This is particularly true since some investigators have argued that all capital expenditures in the late 1960s and early 1970s represent modernization only. This argument is based on the reasoning that no capacity expansion occurred. However, this ignores the replacement of open hearth capacity by basic oxygen furnaces. The method used by TBS represents true modernization of existing facilities since it is based upon the actual expenditures incurred for site-specific units. No previous study utilized this precise method of determining modernization costs.

PRODUCTION OPERATIONS AND MAINTENANCE COSTS

Production operations and maintenance costs are divided into eight categories listed below:

- Labor
- Overhead (includes Sales, General, and Administration)
- Fuel
- Electric Power
- Water
- Raw Materials
- Other
- Credits

Operations and maintenance costs are directly related to the volume of production. For a production process, all categories except labor and overhead require the same use of resources per ton of production regardless of the size or age of the unit in which the production occurs. The amount of labor and overhead required per ton of output is dependent upon the size of unit.

Data on resource requirements were obtained as part of the data request to Arthur D. Little as described above. Resource requirements obtained in this request are summarized in Exhibit 8.

The remainder of this chapter describes the calculation of operations and maintenance cost for each of the eight categories.

LABOR

As can be seen from Exhibit 8, the direct labor hours required to produce a ton of output vary by plant size. For example, in 1972 direct labor requirements for a small basic oxygen furnace are .445 man-hours per ton and .429 man-hours per ton for a large basic oxygen furnace. Total labor hours for this process are the sum of the labor used in each furnace size times the production in that size. However, the labor factors found in 1972 do not remain constant. Productivity gains in the steel industry have averaged 2.3 percent per year.[13] A large portion of this gain is due to more efficient facilities. TBS has determined that such future changes will contribute 0.5 percent per year. Labor productivity is estimated to be 1.8 percent per year which together with more efficient facilities will result in a continuation of the total of 2.3 percent per year. Thus, the labor requirement for each year must be computed from the 1972 amount and the gains in labor productivity.

Productivity gains in any year are calculated according to the following procedure:

$$\text{man-hours per ton} = \frac{\text{1972 man-hours per ton}}{\text{productivity factor}}$$

$$n = \text{number of years since 1972}$$

$$\text{productivity factor} = (1.018)^n$$

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[13] *AISI Annual Statistical Report, 1960-1974*

Man-hours per ton for the basic oxygen furnace in 1977 would be determined as follows:

BASIC OXYGEN FURNACE
MAN-HOURS PER TON
1977

	Small	Large
1972 man-hours/ton	.455	.429
1977 productivity factor	1.093	1.093
1977 man-hours/ton	.407	.392

For purposes of illustration, the previous example of 1977 basic oxygen furnace production of 80 million tons is used. Total labor man-hours would be determined as follows:

BASIC OXYGEN FURNACE
LABOR
(millions)

	Small	Large	Total
Production by size	23.06	56.94	80.00
Man-hours (per ton)	.407	.392	-
Total man-hours	9.39	22.32	31.71

From Exhibit 9 and previous examples, the cost per hour for direct labor in 1977 in current dollars is $13.04 per hour. The total labor cost for production of 80 million tons through the basic oxygen furnace in 1977 is $413.5 million (31.71 million man-hours times $13.04 per man-hour). Following the same procedure for each process will determine total labor costs.

The number of employees can also be computed using these data. The average hours worked per year per employee is 1,940.[14] Thus, the number of people employed can be obtained by dividing the total man-hours of labor required by the average hours worked per employee. Referring to the example above, number of employees would be calculated as below.

BASIC OXYGEN FURNACE
EMPLOYMENT

Total man-hours	31.71 million
Hours per employee per year	1,940
Employment	16,345

OVERHEAD

The cost of overhead is assumed to be in direct proportion to labor costs for each process. Therefore, like labor, overhead varies by size of facility. Overhead by process, by unit size for 1972, is contained in Exhibit 8. Since overhead consists largely of labor and varies in proportion to direct labor, the same increases in productivity apply.

Continuing the example of 1977 basic oxygen furnace production of 80 million tons, overhead would be computed as follows:

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[14] *AISI 1972 Annual Statistical Report.*

BASIC OXYGEN FURNACE
OVERHEAD

	Small	Large
No productivity adjustment		
1975 Overhead per ton	8.40	8.09
1977		
Overhead per ton	10.30	9.93
Productivity factor	1.093	1.093
Overhead per ton (adjusted for productivity)	9.42	9.09
Productivity (million tons)	23.06	56.94
Overhead (million dollars)	$217.2	$517.3
Total Overhead (million dollars)	$734.5	

FUEL

Fuel used in the steel industry consists of several types including oil, coal, and gas. Electricity is computed separately as the category "Electric Power." Coal used directly in steelmaking is accounted for as a raw material. Coal used to generate power is accounted for as fuel. Fuel use by process is summarized in Exhibit 8.

Total fuel use for a process is obtained by multiplying the fuel use per ton in millions of Btu/ton from Exhibit 8 times the production for the process. Continuing the example of basic oxygen furnace production of 80 million tons in 1977, fuel use would be calculated as follows.

BASIC OXYGEN FURNACE
FUEL USE

Production	80 million tons
Fuel use per ton	.22 million Btu
Total fuel use	17.6×10^{12} Btu

The cost for fuel, like the costs for other items, is obtained from Exhibit 9. Fuel costs are then calculated as below:

BASIC OXYGEN FURNACE
FUEL COSTS

1975 fuel cost	\$2.00/million Btu
1977 Inflation factor	1.140
Fuel cost	\$2.28/million Btu
Total fuel use	17.6×10^{12} Btu
Total fuel cost	\$40.1 million

Fuel cost for each process is computed in the manner described above.

ELECTRIC POWER

Costs for electric power include power purchased from utilities and power generated within the steel plant. Rates used are based upon the 1972 average paid by steel firms. Since they are at market prices, electric power costs include the entire cost of operating and maintaining captive generation facilities.

Electric power use and cost are determined in the same manner as fuel use and cost above. Power use in kilowatt-hours per ton is contained in Exhibit 8. Cost per kilowatt-hour is shown in Exhibit 9. A sample calculation for 80 million tons of basic oxygen furnace production in 1977 is described below:

BASIC OXYGEN FURNACE
ELECTRIC POWER COST

Production	80 million tons
Power use per ton	30.44 kilowatt hours
Total power use	2435.2 million kilowatt hours
1975 power cost	$.0215/kilowatt hour
1977	
Inflation factor	1.123
Power cost	$.0242/kilowatt hour
Total power use	2435.2 million kilowatt hours
Total power cost	$58.9 million

WATER

Costs for water are calculated in the same way as costs for fuel and electric power above. Water use per ton and cost per thousand gallons are obtained from Exhibits 8 and 9, respectively. A sample calculation for the basic oxygen furnace described above is presented on the following page.

BASIC OXYGEN FURNACE
WATER COSTS

Production	80 million tons
Water use per ton	2.31 thousand gallons
Total water use	184.8 billion gallons
1975 water cost	$.127/thousand gallons
1977	
Inflation factor	1.140
Water cost	$.145/thousand gallons
Water use	184.8 billion gallons
Total water cost	$26.8 million

RAW MATERIALS

The major raw materials used by the steel industry are iron ore, coal, and scrap. Costs for each of these materials are calculated according to the same procedure. The use per ton of production in each process is obtained from Exhibit 8, and the cost per ton of raw materials is obtained from Exhibit 9.

The examples below describe how to calculate operating costs for each of these categories.

Iron ore can be in three forms: lump ore, pellets, or sinter. In this analysis, each type of iron source has been converted to equivalent amounts of iron ore. Utilizing the example of 100 million tons of blast furnace production in 1977, from Exhibit 8, .54 tons of pellets, .35 tons of sinter, and .69 tons of ore are required per ton of iron produced. The ore requirements for sinter are calculated under that process so that total iron ore resources direct to the blast furnace are 1.23 tons (.54 + .69).

BLAST FURNACE
IRON ORE COSTS

Production	100 million tons
Iron ore use per ton	1.23 tons
Total ore used	123 million tons
1975 cost of iron ore	$23.09/ton
1977	
Inflation factor	1.183
1977 cost	$27.32/ton
Total ore used	123 million tons
Cost of ore	$3,360 million

Coal costs included in operating and maintenance are for coal used in the ironmaking process. Coal used to fire boilers for energy production is included in the cost of power and fuel. From Exhibit 8, use of coal in coke ovens is 1.43 tons for every ton of coke. The 1975 price of metallurgical for coking is $36.13 per ton in Exhibit 9. Assuming 60 million tons of coke oven production in 1977, coal costs would be calculated as follows:

COKE OVEN
COAL COSTS

Production	60 million tons
Coal use per ton	1.43 tons
Total coal used	85.8 million tons
1975 cost of coal	$36.13/ton
1977	
Inflation factor	1.283
Cost of coal	$46.35/ton
Total coal used	85.8 million tons
Cost of coal	$3,977 million

Scrap is used primarily in the steelmaking furnaces. Scrap generated in the various steelmaking processes is included at the same cost as scrap purchased on the market. However, this same amount is also credited to the processes which generated the internal scrap. To illustrate the cost of scrap, the example of basic oxygen furnace production from earlier sections will again be employed.

BASIC OXYGEN FURNACE
SCRAP COST

Production	80 million tons
Scrap use per ton	.32 tons
Scrap use	25.6 million tons
1975 cost of scrap	$86.96/ton
1977	
Inflation factor	1.158
Cost of scrap	$100.72/ton
Scrap used	25.6 million tons
Total cost of scrap	$2,578 million

OTHER RAW MATERIALS

Other raw materials includes primarily the cost of chemicals such as acids and non-ferrous metallics used as alloys and in coatings. Since there is such a variety of components, other raw material costs are stated in dollars per ton of production. The use of other raw materials, $7.85, obtained from Exhibit 8, is in 1975 dollars per ton. The following calculations hold for the basic oxygen furnace example used above.

BASIC OXYGEN FURNACE
OTHER RAW MATERIALS COST

1975 other raw materials	$7.85 per ton
1977	
Inflation factor	1.130
Cost of other raw materials	$8.87 per ton
Production	80 million tons
Total other raw materials	$709.9 million

OTHER COSTS

Other costs per ton of production are listed in Exhibit 8. This category includes maintenance, other raw materials, other utilities, and miscellaneous costs. As seen above, other raw materials have been separately computed. In addition, other utilities includes water, which has also been separately calculated above.

CREDITS

Some items of operations and maintenance expense are actually credits. This occurs because a steel company either utilizes a by-product of one process in another process in place of purchasing it or outright sells the by-product for gain. Items in which credits occur are scrap, energy, and other raw materials. Calculation of each of these items which reduces operating costs is described below.

Scrap is generated in most steel processes. It is also, as seen above, a major raw material input to the steel-making furnaces. The scrap generated by each process is described in Exhibit 8. Scrap generation is stated in tons of scrap per ton of output for the process. The cost of scrap can be obtained from Exhibit 9. Scrap is charged to using processes and credited to generating processes at the same market price. Even the basic oxygen furnace generates .02 tons of reusable scrap per ton of output. The basic oxygen furnace example above is extended to cover scrap credits.

BASIC OXYGEN FURNACE
SCRAP CREDIT

Production	80 million tons
Scrap use per ton	.02 ton
Scrap generated	1.6 million tons
1975 scrap cost	$86.96/ton
1977	
Inflation factor	1.158
Scrap cost	$100.72/ton
Scrap generated	1.6 million tons
Scrap credit	$161 million

Energy credits occur either when heat generated by a process is used, or when a by-product such as blast furnace gas is burned as a fuel. The amount of energy credit in millions of Btu per tons of output is contained in Exhibit 8 with corresponding prices in Exhibit 9. The blast furnace used in the section on iron ore costs is also used below to illustrate calculation of the energy credit.

BLAST FURNACE
ENERGY CREDIT

Production	100 million tons
Energy credit per ton	4.43 /million Btu/ton
Energy credit	443 X 10^{12} Btu
1975 cost of energy	\$2.00/million Btu
1977	
Inflation factor	1.140
Cost of energy	\$2.27/million Btu
Energy credit	443 X 10^{12} Btu
Total Credit	\$1.01 billion

Other raw materials result in a credit when, for example, acid, other chemicals, or metallics can be reclaimed and sold or used again like the credits above. The credit for other raw materials can be obtained from Exhibit 8. Note that the amount in Exhibit 8 is given in dollars per ton. Once again, the basic oxygen furnace example will be used to illustrate the method of calculation.

BASIC OXYGEN FURNACE
OTHER RAW MATERIALS CREDIT

1975 other raw materials cost	$1.00/ton
1977	
Inflation factor	$1.13
Other raw material cost	$1.13/ton
Production	80 million tons
Total other raw material credits	$90.4 million

3. WATER POLLUTION CONTROL COSTS

The U.S. steel industry uses daily over 3.5 million gallons of contact water in steelmaking and finishing process operations and over 7 million gallons of cooling water.[1] Supply and quality requirements for water input flows differ vastly from process to process. Each process contributes different flows of wastewater effluent. Costs of water cleanup vary and therefore must be examined separately for each process. The cost of compliance with water pollution regulations, both promulgated and anticipated, is incremental to the cost of steel production.

This section of Volume II examines the historical background of The Federal Water Pollution Control Act Amendments of 1972 and of the Effluent Limitations Guidelines which that statute charged the Environmental Protection Agency to develop. Later in this section the cost methodology used by the EPA technical contractor, Cyrus Rice Division of NUS Corporation (NUS/Cyrus Rice), in developing the Guidelines is reviewed. The remaining topics describe the Temple, Barker & Sloane, Inc. water pollution treatment cost model for the steel industry.

The TBS water pollution analysis is keyed directly to the process of steelmaking and finishing. It does not address certain limitations such as OSHA regulations which may be related to but, nonetheless, are external to abating industrial process discharges. Further, this analysis does not consider pretreatment of wastestreams, municipal water treatment, or the regulations imposed by state and local authorities which are in excess of the Federal Water Pollution Control Standards. The TBS study examines wastewater treatment in the industry both as it is currently regulated by the EPA Effluent Limitations Guidelines and by guideline standards for on-site power generation and electroplating, and also as it is expected to be regulated in the future.

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[1] *U.S. Steel, The Making, Shaping, and Treating of Steel, 1971.*

THE DEVELOPMENT OF EFFLUENT LIMITATIONS GUIDELINES

To discharge its responsibilities pursuant to the statutory requirements of The Federal Water Pollution Control Act Amendments of 1972, the Environmental Protection Agency contracted with NUS/Cyrus Rice to conduct an extensive study of the steel industry to develop effluent limitations guidelines. For purposes of analysis, the operations of the steel industry were divided into two parts--referred to hereafter as Phase I and Phase II. Phase I includes raw material preparation, ironmaking, steelmaking, and continuous casting. Phase II includes breaking of ingots into primary forms and other processes through finishing and coating of steel products.

The first segment of the NUS/Cyrus Rice study resulted in effluent limitations for Phase I processes. The standards were proposed in the Federal Register on February 19, 1974 and subsequently promulgated. The Phase I Development Document was published and released in June 1974.[2]

Later, the Phase I guidelines came under judicial review in a court case instituted by the AISI and several steel companies. The resulting decision handed down in November

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[2] *EPA-440/1-74-024-a, Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the STEELMAKING Segment of the Iron and Steel Manufacturing Point Source Category, June 1974.*

1975 by the U.S. Court of Appeals, Third Circuit remanded the Guideline for review of certain sections by the EPA.

A draft version of the guideline limitations for Phase II processes was published in the Federal Register in August 1975. This Advanced Notice of Proposed Regulations (ANPR) document[3] did not have the legal standing of proposed standards. Subsequently, guidelines on certain Phase II processes were revised as alterations in discharge parameters; treatment technologies and the cost implied by these technologies were suggested by the technical contractor. New guideline costs were developed which superceded the ANPR document. This report is based on these proposed Phase II guidelines published in the March 29, 1976 Federal Register.[4]

STUDY METHODOLOGY OF EFFLUENT GUIDELINES SUBCONTRACTOR

NUS/Cyrus Rice first studied the "iron and steel manufacturing" point source category to determine whether separate limitations and standards would be required for different segments of the point source. The result was a subdivision of the industry into 30 subcategories. In Exhibit 18, this categorization is compared to the 28 production processes employed in this study.

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[3] *EPA-440-1-75/048, Development Document for Advanced Notice of Proposed Rulemaking for Effluent Limitations Guidelines and New Source Performance Standards for the Hot Forming and Cold Finishing Segment of the Iron and Steel Manufacturing Point Source Category, August 1975.*

[4] *EPA-440/1-76/048-b, Development Document for Interim Final and Proposed Effluent Limitations Guidelines and New Source Performance Standards for Forming, Finishing, and Specialty Steel Segments of the Iron and Steel Manufacturing Point Source Category, March 1976.*

A principal source of data employed by NUS/Cyrus Rice engineers in establishing effluent limitations standards for each of these subcategories was on-site plant visits to exemplary treatment plant facilities. Initially, a survey of existing treatment facilities and their performance was made from information obtained through State Environmental Agencies and their permit programs in particular, from literature searches, from personal contact of study contractors, and from EPA personnel. A list of candidates for plant visits was compiled consisting of those plants which were considered by more than one source to be providing the best waste treatment available, that is, "exemplary" treatment. The greatest number of candidate plants were located in the 15 states which together contribute over 90 percent of steel production.

Within each process group from one to five plants operating exemplary treatment facilities were visited, interviewed, and samples obtained. Flows of wastewater and raw waste characteristics for each subcategory were identified. The effluent limitations guidelines regulate only those constituents considered to be major pollutants in each subcategory investigated.

The range of available treatment equipment existing for each subcategory was identified. This included complete evaluation of the level of control afforded from the application of each kind of treatment. Non-water quality elements such as energy requirements, noise, air pollution, etc., were also analyzed.

To accomplish a complete evaluation of treatment technologies, it was first necessary to establish a baseline or reference level of treatment being practiced in the industry to clean raw waste loads. "Base" level of abatement was

Table 1

POLLUTANT PARAMETERS: BASIC OXYGEN FURNACE

(effluent associated with Scrubbers
or Wet air pollution control methods)

GUIDELINE LEVELS	FLOW	POLLUTANT PARAMETERS	LEVELS OF TREATMENT TECHNOLOGY
	gals/ton	lbs/ton of product[a] 30 consecutive day max. av.	
Raw	600		
Base	600	Suspended Solids: .4420 Flouride: .1658 pH: 6.0 - 9.0	A. Aqueous Discharge from primary scrubber to classifier to thickener. "Once through" overflow to sewer, underflow through vacuum filters filter cake recycled to sinter plant or landfilled, filtrate recycled to thickener.
BPCTCA	50	Suspended Solids: .0280	B. To A, add magnetic and/or chemical polymer flocculation
			C. To B, add thickener overflow recycle system with blowdown; neutralization of blowdown stream
BATEA	50	Suspended Solids: .0104 Flouride: .0084 pH: 6.0 - 9.0	D. To C, add blowdown treatment via settling with coagulation; lime treatment and neutralization
NSPS or BADCT	Same as BATEA	Same as BATEA	Same as BATEA
			E. To D, add activated alumine treatment; filtration

[a] *The unit "lbs/ton" is utilized in this report rather than "lbs/1000 lbs" as in the EPA Development Document for consistency with reporting of units of production.*

Source: EPA-440/1-74-024-a, Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the STEELMAKING Segment of the Iron and Steel Manufacturing Point Source Category, June 1974, p.5, 11; TBS calculation.

It should be noted that effluent flows requiring treatment originate from several sources. Certain wastewater flows are directly linked to a process; that is, they are generated in the production process where water is used in direct contact with steel to cool, quench, or wash it. Other flows are related to the storm runoff from raw material stockpiles. The current Effluent Limitations Guidelines regulate the process-specific and the miscellaneous runoff categories. Certain non-process related water pollution flows are not yet covered by existing guidelines but have been examined in the TBS study. These include non-contact cooling water blowdown and ancillary water associated with on-site power generation. Costs for non-process water treatment subcategories, including the miscellaneous runoffs category which is currently regulated, are allocated to industry-wide operations rather than to individual process operations.

Table 1 above illustrates several important facets of the study methodology used in developing the Effluent Guidelines. The levels of technology described by NUS/Cyrus Rice engineers are keyed to the use of particular treatments and equipment. However, other technologies may be employed by the industry if they meet required guideline standards. The technologies are end-of-process methods which can be added onto existing productive and existing treatment facilities. The levels of treatment are generally incremental. Thus, substantially all equipment installed above Base level to meet BPCTCA standards. In other words, BATEA regulations are normally met by installing Base plus BPCTCA plus BATEA equipment. In developing treatment technologies to meet guideline standards, NUS/Cyrus Rice engineers identified treatment levels achievable with specific pieces of equipment or techniques. These levels were identified by alphabetical letters. In the case of the "basic oxygen furnace-wet" process, these levels correspond in the following manner to guideline standards:

Guideline		Treatment Level
Base	=	A
BPCTCA	=	B & C
BATEA	=	D
NSPS	=	Same as BATEA
--	=	E

The "E" level (see Table 1 for detail of treatment technology) was treatment seen in operation during the plant survey in at least one facility. However, since this plant operated at above the BATEA level of treatment, the "E" technolgoy was not included in the Guideline standard.

A complete summary of the proposed treatment model levels for all processes and their correspondence with Guideline levels is contained in Exhibit 19.

In the example of the basic oxygen furnace-wet, it was determined that the NSPS discharge standard would be the same at BATEA standard. That is, no additional reduction of pollutant loads and/or effluent flows above BATEA level of treatment is required as a standard for new sources. Similarly, it was determined that nearly all Phase I and Phase II processes meet BADCT at BATEA level of treatment. New Source Performance Standards are thus essentially the same as those for BATEA.[6]

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[6] *Minor exceptions to this rule for certain Phase II processes are described in the previously cited Development Document.*

COST PARAMETERS OF THE EFFLUENT LIMITATIONS GUIDELINES

NUS/Cyrus Rice estimated costs in each subcategory for a "model plant." Production data in the year 1972 was collected. This information was tabulated with the number of plant facilities operating in the U.S. in that year in each process subcategory. By dividing production tonnage by number of plants and then by an operating year assumption for each process, an average or "model" plant size was established. The engineering cost estimates are additive with each Effluent Guideline level, and all costs of water pollution treatment are assumed to be incremental to production costs.

Effluent flow rates for each process and each guideline level of pollution abatement were established based on data gathered in the "exemplary treatment" plant survey. Exhibit 20 sets forth the flow rates, model plant size, and operating year assumptions for each subcategory. Again, based on survey data, general industry knowledge, and engineering analysis, a treatment process model and flow diagram was developed for the model plant in each subcategory.

Finally, engineering cost estimates were made of capital and operating costs for treatment facilities at each model plant. Costs were generated in August 1971 dollars for the total annual tonnage produced by each model plant. Table 2 below presents an example of the cost estimates developed by NUS/Cyrus Rice for the basic oxygen furnace-wet model plant. For subsequent use in PTm(Steel) all costs were converted to current dollars.

Table 2

WATER EFFLUENT TREATMENT COSTS
STEEL INDUSTRY

Basic Oxygen Furance (Wet Air Pollution Control Methods) Subcategory

(1971 dollars)

		BPCTCA		BATEA	
Treatment or Control Technologies Identified under Item III of the Scope of Work:	A	B	C	D	E
Investment	$1,308,722	$ 27,058	$437,326	$363,251	$359,630
Annual Costs:					
Operations & Maintenance	45,805	947	15,306	12,713	12,587
Sludge Disposal	138,627			1,040	
Energy & Power	30,000	675	11,925	10,575	4,500
Chemical		131,400	1,822	6,197	29
TOTAL	$ 214,432	$133,022	$ 29,053	$ 30,325	$ 17,116

Source: EPA-440/1-74-024-a, Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the STEELMAKING Segment of the Iron and Steel Manufacturing Point Source Category, June 1974, p. 295.

CAPITAL COSTS

The total capital investment required to treat effluent wastes from the basic oxygen furnace-wet model plant is:

$1,308,722	at Base level
+ 464,384	at BPCTCA level
+ 363,251	at BATEA level
$2,136,357	for TOTAL TREATMENT

Costs of level E were not included in any guidelines costs at any level since they represented expenditures for treatment equipment which was not necessary to achieve BATEA level of treatment and thus was not included in the guidelines standard.

Capital expenditure costs are at best averaged estimates. Construction and equipment costs are dependent on many variable conditions. The NUS/Cyrus Rice cost estimates are based on installation of abatement facilities at existing steel plants. That is, water treatment equipment on each model plant is assumed to be retrofit to production processes already in place and in operation. In-place treatment at this model plant was assumed to be at Base level. Base level of treatment was defined by NUS/Cyrus Rice to be "that level of treatment (which) was already in existence for practically all plants within the industry in any given subcategory."[7] As such, Base treatment is the least common denominator of water treatment. Abatement equipment added on to existing treatment facilities to meet BPCTCA and BATEA standards is contained within the limits of site location of the production unit and is erected on a clean site, such as a nearby parking facility, railroad

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[7] *EPA-440/1-74-024-a, Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the STEELMAKING Segment of the Iron and Steel Manufacturing Point Source Category, June 1974.*

bed, or other land in close proximity to the steelmaking process unit. The treatment facilities on which these capital expenditures are based are not installed inside the production mill unit. The assumption is that in most cases treatment can be constructed nearby without disruption of production and installed with a minimum of downtime.[8] Although in certain instances during plant surveys NUS/Cyrus Rice engineers observed treatment facilities being installed simultaneously with new productive capacity at greenfield locations, the capital costs of these treatment installations were not the basis of costs developed for model plants in each subcategory.

Capital costs do not include land acquisition costs, piping and interconnecting utility runs, or expansion of supporting utilities to accommodate treatment requirements. They do include engineering fees of 15 percent, contractor's overhead and profit of 10 percent, and a contingency of 15 percent.

Capital costs of pollution abatement treatment, like many industrial facilities, exhibit economies of scale. That is, the larger the treatment facility, the less the cost per ton of capacity. NUS/Cyrus Rice engineers estimate that these economies of scale can be determined from costs for the model plant by using a scale factor of 0.6.[9] While the scale factor for individual treatment elements may vary, the 0.6 represents an average.[10] Thus capital costs are assumed to fit from an equation of the form $Y = AX^B$, where Y is the capital cost, B is the scale factor, X is the plant size, and A is a constant determined by the capital cost for the model plant.

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[8] *Conference with NUS/Cyrus Rice engineers.*

[9] *EPA Development Document, Phase II draft for interagency review, February 1976, line 5343.*

[10] *This is in agreement with AISI study, Table B-7, which used an average scale factor of 0.65 with a range of 1.0 to 0.36.*

For example, for the basic oxygen furnace-wet, capital costs in 1975 dollars are calculated as follows:

Y = Capital cost = \$623,207
X = Capacity = 7,590 tons/day
B = Scale factor = 0.6

Solving the equation $Y = AX^B$, we see:

$$A = Y \div X^B$$

Substituting the values above, A is determined to be 2,929.44.

Now the capital cost for treatment of a basic oxygen furnace-wet of a size different from the model plant can be obtained from this equation:

$$\text{Capital cost} = 2{,}929.44\ (\text{plant size})^{.6}$$

OPERATIONS AND MAINTENANCE COSTS

The total cost of operating a water pollution treatment facility is separated into the following elements in the Effluent Guidelines:

- Labor, maintenance materials, and supplies
- Chemicals
- Disposal of sludge, oil, and other wastes
- Energy
- Other (including carbon column rental).

In this analysis, all costs are based on the assumption that production at the model plant is being utilized at 100 percent of capacity.

The composite operations and maintenance item which includes labor costs for operations, labor costs for maintenance, and materials and supplies is calculated as a percentage of capital costs. Referring to the basic oxygen furnace-wet model plant example above in Table 2, the costs of these elements (in 1971 dollars) are:

$45,805	at Base level
+16,253	at BPCTCA level
+12,713	at BATEA level
$75,041	for TOTAL TREATMENT

That is, at each level of treatment the cost is 3.5 percent of the capital cost. Operations and maintenance costs do not vary with production, reflecting the almost continuous operation of a basic oxygen furnace and the need for continuous maintenance of the pollution control equipment--which is a function of size, not of operating level.

Chemical costs are directly related to the volume of production and effluent flows generated through each process. Costs vary by process according to the nature, volume, and cost of treatment chemicals used. In the basic oxygen furnace model plant, chemicals are added in both BPCTCA and BATEA treatment at a cost (in 1971 dollars) of $133,222 and $6,197, respectively.

Disposal of sludge, oil, and spent pickle liquor wastes are again a function of production volume. NUS/Cyrus Rice engineers identify this cost as primarily a contract hauling cost. Only sludge disposal is applicable to the basic oxygen furnace process since no acids are used. The sludge is primarily generated at Base level of treatment, and a cost of $138,627 for disposal is incurred by the model plant. No sludge is associated with BPCTCA level of cleanup and only a minimal amount is generated at BATEA level.

Energy costs as developed by the EPA technical contractor are entirely costs of electric power and steam. No other fuel is assumed to be used directly. However, coal, natural gas, and/or other fuels might be used in on-site generation of electric power, in which case they would be accounted for in that process. In the coking process, the totals reflect charges for consumption of steam by treatment facilities. However, all steam requirements are internally generated by steelmaking process units, and thus purchase is not necessary. NUS/Cyrus Rice engineers priced energy costs at a figure of $75 per horsepower-year, of $.01145 per kwh in 1972 dollars. Based on general knowledge of current electric utility rates and conforming with data collected in the Arthur D. Little study on power rates actually paid by the steel industry in 1972, TBS determined that the above cost was lower than the national average. Therefore, a charge of $.014 per kwh in 1972 dollars was used in this analysis. Referring to the basic oxygen furnace-wet model plant example, the costs (in 1971 dollars) of power per ton of raw steel treated are:

$30,000	at Base level
+12,600	at BPCTCA level
+10,575	at BATEA level
$53,175	for TOTAL TREATMENT

Miscellaneous "other" costs are included in total operations and maintenance costs for some processes. In the effluent from blast furnace and coking operations, for example, certain residual organic materials are not cleaned up by treatment technologies at any guideline level. For purposes of chlorination to rid final effluent discharge (or "blowdown" as it is referred to frequently in the guideline) of organic wastes, carbon drums are leased from a subcontractor. The basic oxygen furnace example above includes no miscellaneous operating costs.

The Effluent Limitations Guidelines examine the costs of water pollution abatement as uniquely allocated to each separate subcategory. In reality many steel plants operate mills which commingle resulting effluent flows prior to treatment. The Effluent Guidelines do not address the possibility of efficiencies and resulting cost savings which commingling may afford steel companies. The TBS analysis investigates the potential of this approach to water treatment in a sensitivity analysis of the Effluent Limitations Guidelines water costs.

The Effluent Guidelines study generally did not quantify credits for recoverable by-products which water cleanup may offer. Only in the case of the regeneration of spent pickle liquor was credit actually quantified. Although the potential costs savings from other credits have not been incorporated in the TBS cost model, Exhibit 21 suggests the variety of recoverables linked to each process.

The cost development of the Effluent Limitations Guidelines makes no differentiation for facility age and facility location. It is assumed that each plant in operation has an equal ability to treat its own wastes. Although effluent flows vary greatly among facilities, thus altering the cost of cleanup, the model plant represents the average cost.

For use in PTm(Steel) the model plant data developed by NUS/Cyrus Rice were broken down into costs on a per ton basis. All costs were first inflated by the GNP implicit price deflator from August 1971 dollars to year-end 1972 dollars. This was done solely for the purpose of comparability with other cost data developed by ADL in its study for the American Iron and Steel Institute. Later all costs were inflated in the TBS water pollution treatment model to current dollars and reported in 1975 constant dollars.

A close examination of the basic oxygen furnace-wet example in Table 3 will exhibit the "per ton" costs which were developed for each process. The method by which TBS calculated these costs is as described below.

All costs (both capital and operating) above were developed from data found in Table 2. For example,

	A (Base)
Capital Cost:	$1,308,722
X 1.026 (inflate to 1972 dollars)	1,342,749
÷ 7,590 tons per day X 360 tons per year	2,732,400
= cost per ton	$ .491

Table 3

BASIC OXYGEN FURNACE-WET

Costs: 1972 $/ton	Base	BPT	BAT	Total
Capital Cost: Total	$0.491	$0.174	$0.136	$0.801
Operating Cost: Total	0.080	0.061	0.011	0.152
1. Total Labor & Maintenance	0.017	0.006	0.005	0.028
2. Sludge Disposal	0.052	0.000	0.000[a]	0.052
3. Total Energy	0.015	0.006	0.005	0.026
Power	0.015	0.006	0.005	0.026
Fuel	0.000	0.000	0.000	0.000
Steam	0.000	0.000	0.000	0.000
4. Chemicals	-	0.050	0.002	0.052

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[a] *Note that while the model plant (see Table 2) incurs a minimal charge for BAT sludge disposal, on a per ton basis this cost is not significant.*

Source: EPA-440/1-74-024-a, Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the STEELMAKING Segment of the Iron and Steel Manufacturing Point Source Category, June 1974, p. 295.

A full presentation of "per ton" capital and operating costs for all processes follows in Exhibits 22, 23 and 24, which detail Base, BPCTCA, and BATEA treatment costs, respectively. As in the basic oxygen furnace example discussed above, all line items are expressed as a per ton cost in 1972 dollars.

ASSOCIATION OF PRODUCTION PROCESSES WITH WATER POLLUTION TREATMENT CATEGORIES

The 28 production processes utilized throughout this analysis are based upon the individual unit operations of which the steel industry is comprised. Each process produces only one output and all processes are linked together according to relationships which result in processing from raw material to finished product. The effect of a change in production requirements for a single product can be determined for each process. Because of this relationship, these processes accurately reflect the production requirements and costs of the steel industry.

The 30 water pollution control subcategories which form the basis of the Effluent Limitations Guidelines are based upon wastewater streams with similar pollutant contents. Thus these subcategories offer the most accurate level for analysis of pollution control costs. However, these subcategories do not always correspond directly to the actual production processes. In some cases, a production process may generate more than one waste stream with very different requirements for pollution control equipment. In other cases, a subcategory may include waste streams from several production processes which have similar characteristics. Finally, the waste stream from a given process may permit treatment alternatives so different that separate subcategories are specified. Exhibit 18, which matches production processes with water treatment subcategories, suggests this difference.

It is necessary to base production requirements and costs on production processes, since the water pollution control subcategories do not represent the physical flow of production. That is, shifts in production requirements for a given product may not be clearly determined for the water pollution control subcategory without first considering the actual production process. For example, a ten-ton increase in need for hot rolled bars might appear to require a ten-ton increase in the subcategory "hot forming section." However, when the production processes are considered, it becomes clear that hot forming section costs must be incurred at the bar mill and also at the billet mill which requires hot forming section treatment. The analysis is further complicated by the fact that some billets are produced by continuous casting and thus do not incur hot forming section costs. Also the yield loss in each production process must be taken into account.

After determining production and capacity requirements for each process, it is necessary to associate these requirements with the corresponding subcategories to determine the pollution control treatment costs. The procedure for making this association is described in this chapter. Subcategories or processes may appear in more than one relationship where the actual association is complex.

SUBCATEGORIES WHICH INCLUDE A SINGLE PRODUCTION PROCESS

Subcategories which coincide with a single production process are the most easily dealt with. Production and new capacity requirements are the same for the subcategory as for the production process. Subcategories in this group are listed below together with their corresponding production processes.

SUBCATEGORIES ASSOCIATED
WITH A SINGLE PRODUCTION PROCESS

Subcategory	Production Process
Sintering	Sintering
Blast Furnace	Blast Furnace
Hot Forming--Hot Sheet and Strip	Hot Rolled Sheet
Hot Forming--Flat Plate	Plate
Hot Coating--Galvanizing	Hot Coating--Galvanizing
Hot Coating--Terne	Hot Coating--Terne
Cold Coating--Tin	Cold Coating--Tin
Cold Coating--Chrome	Cold Coating--Chrome

SUBCATEGORIES WHICH INCLUDE MORE THAN ONE PRODUCTION PROCESS

Subcategories which include more than one production process are listed below with the corresponding production processes.

SUBCATEGORIES WHICH INCLUDE MORE
THAN ONE PRODUCTION PROCESS

Subcategory	Production Process
Continuous Casting	Continuous Casting--Slabs Continuous Casting--Blooms and Billets
Hot Forming--Primary	Primary Breaking--Slabs Primary Breaking--Blooms
Hot Forming--Section	Primary Breaking--Billets Heavy Structurals Hot Rolled Bars Wire Products
Vacuum Degassing	Open Heath Furnace Basic Oxygen Furnace Electric Furnace
Batch Sulfuric Pickling	Bar and Rod Pipe and Tube Wire Products Plate

In each case listed above, the wastewater streams from each production process were considered so similar that a single subcategory described the required abatement treatment. The method of associating the subcategories and production processes for each of these cases is described below.

Continuous Casting

Treatment of water used in the continuous casting process is the same whether the product is a billet, a bloom, or a slab. Therefore, the cost of effluent control at every guideline level is assumed to be the same for each ton continuously cast regardless of the type of form produced.

Hot Forming Primary

In the same manner as continuous casting, the hot forming primary subcategory utilized in the Effluent Guidelines is associated with the primary breaking of ingots, which were conventionally cast, into either blooms or slabs. Each ton of production is assumed to incur the same treatment costs. Thus, from Exhibits 22 through 24 the cost of capital for water pollution control treatment is identical whether the breaking mill produces slabs or blooms.

Hot Forming Section

The allocation of production to the hot forming sections subcategory is similar to those above, but involves a more complex set of assumptions. The section treatment category is applicable to the billets, heavy structurals, hot finished bar, cold finished bar, and wire product mills. In the flow of production between these processes the steel may be reheated one or more times depending upon configuration of the plant or company. After each heating, water is used in direct contact for removing scale, and for quenching and cooling the hot metal. Correct statement of abatement costs for the subcategory requires that the precise number of times the steel is heated and thereby incurs section costs be specified. The following table contains the percent of each production process which requires hot forming section treatment costs.

ALLOCATION OF HOT FORMING: SECTION WATER TREATMENT COSTS

Production Process	% Treated
Primary Breaking--Billets	18.7%
Heavy Structurals & Rails	59.7%
Wire Products	0.0%
Bars and Rods	121.7%

Only 18.7 percent of production in the primary breaking billet mill requires hot forming section water treatment because only this percent must be reheated. Most primary breaking of billets occurs at a plant where blooms or ingots are received hot from the previous process. Thus no reheat and subsequent scale removal is necessary.

More than 100 percent of bars and rods require section treatment since in producing bars, the steel may be reheated and rolled several times. Each time the steel is heated, scale is removed and wastewater results.

Vacuum Degassing

Vacuum degassing occurs for only a portion of the steel produced from basic oxygen and electric furnaces. The treatment of air emissions results in a wastewater stream which must be treated. All production which is vacuum degassed requires water treatment, but only the percent of production from each furnace as set forth below requires degassing.

VACUUM DEGASSING
ALLOCATION OF PRODUCTION FROM
EACH STEELMAKING FURNACE

Furnace	Percent of Production Vacuum Degassed
Basic Oxygen Furnace	33.3%
Electric Furnace	40%

Batch Sulfuric Pickling

Some portion of the production from several finishing mills requires batch sulfuric pickling. The amount of batch sulfuric production is derived from these ratios. The portions are as follows:

BATCH SULFURIC PICKLING
ALLOCATION OF PRODUCTION PROCESSES

Production Process	Percent of Production Pickled
Bar and Rod	38.3%
Pipe and Tube: Seamless	60%
Wire Products	82%
Plate	18%

SUBCATEGORIES WHICH INCLUDE PART OF A PRODUCTION PROCESS

Some production processes produce wastestreams so different that separate subcategories are specified for each one. This may occur because the water results from different types of air pollution control equipment or because of basic differences in production process equipment design. These subcategories and their associated production processes are listed below:

SUBCATEGORIES WHICH INCLUDE PART OF A PRODUCTION PROCESS

Subcategory		Production Process
Open Hearth Wet Open Hearth Dry		Open Hearth Furnace
Basic Oxygen Furnace:	wet semi-wet dry	Basic Oxygen Furnace
Electric Furnace:	wet semi-wet dry	Electric Furnace
Sintering:	wet dry	Sintering
Welded Integrated Welded Isolated		Welded Pipe and Tube
Seamless Integrated Seamless Isolated		Seamless Pipe and Tube
Continuous Hydrochloric Continuous Sulfuric		Pickling & Oiling
Recirculation Direct Application Combination		Cold Rolling
Physical Chemical Biological		By-Product Coking

Steelmaking Furnaces

Steelmaking furnaces are considered as a group since the reason each requires more than one water treatment subcategory is the same. Wastewater associated with steelmaking furnaces is generated in the course of air pollution abatement. Steelmaking furnaces which employ venturi scrubbers (scrubbers) or electrostatic precipitators (ESPs) use water to aid in cleansing emissions from gases. These air treatment technologies are called "wet" and "semi-wet," respectively. The dirty effluent from both scrubbers and ESPs is treated prior to discharge into receiving water streams. Furnace facilities which use fabric filters or "baghouse" dust collectors only are considered "dry" shops and employ no water during air treatment.

The TBS methodology allocates all furnace capacity to one of the three treatment types so that water treatment costs are applied correctly to molten steel tonnages associated with each furnace type. The breakdown, developed from NUS/Cyrus Rice engineering data, is as follows:

STEELMAKING

	Air Treatment Technology		
Furnace	Wet	Semi-Wet	Dry
Open Hearth	39%	0%	61%
Basic Oxygen Furnace	65%	24%	11%
Electric	25%	6%	69%

This means that the technology and associated water treatment costs developed for basic oxygen furnaces using scrubbers to cleanse stack gases, i.e., the basic oxygen furnace-wet process, are applied to 65 percent of all tons produced in any given year in basic oxygen furnaces. Similarly, basic oxygen furnace-semi-wet treatment costs are attributed to 24 percent of production. The remaining 11 percent of basic oxygen furnace production requires no water treatment since it is assumed to be produced in shops employing dry air treatment methods which use no water.

Sintering

Like steelmaking furnaces, air treatment of sinter strand pollution generates water flows which require treatment. The allocation of production with respect to water treatment is as follows:

SINTERING

	Air Treatment Technology		
	Wet	Semi-Wet	Dry
Sintering	17%	0%	83%

Pipe & Tubing

The effluent guidelines provide differing water treatment costs for effluent associated with production of pipes and tubing in both integrated mills and in isolated mills. Plant survey data showed varying effluent flows and discharge parameters for these different types of production facilities. Therefore, several sets of treatment technologies and costs were developed for the pipe and tubing process. Based on NUS/Cyrus Rice engineering estimates, the following treatment allocations are appropriate.

PIPE & TUBING
ALLOCATION OF PRODUCTION BY MILL TYPE
1972

Welded Pipe & Tube:	Integrated mills:	50%
Welded Pipe & Tube:	Isolated mills:	50%
Seamless and Other Pipe & Tube:	Integrated mills:	81.82%
Seamless and Other Pipe & Tube:	Isolated mills:	18.18%

Pickling and Oiling

Pickling and oiling may be performed using either hydrochloric or sulfuric acid. Each of these in turn may be treated by two different methods: neutralization or acid recovery. Thus, pickling and oiling results in four subcategories. The table below lists the subcategories and the percent of pickling and oiling production treated by each subcategory.

PICKLING AND OILING
ALLOCATION OF PRODUCTION TO SUBCATEGORIES

Subcategory	Percent of Production
Hydrochloric--Acid Recovery	16.3%
--Neutralization	40.9%
Sulfuric--Acid Recovery	27.4%
--Neutralization	15.4%

Cold Rolling

Treatment of wastewater containing waste rolling solution from cold rolling mills may be accomplished by one of three alternative subcategories. These subcategories with the percent of cold rolling production utilizing each are specified below:

COLD ROLLING
ALLOCATION OF PRODUCTION BY SUBCATEGORIES

Subcategory	Percent of Production
Recirculation	54%
Direct Application	13%
Combination	53%

By Product Coking

Like cold rolling, effluent from by-product coking may be treated by alternative methods. The alternative subcategories and the percent of coking production allocated to each is as follows:

BY-PRODUCT COKING
ALLOCATION OF PRODUCTION TO SUBCATEGORIES

Subcategory	Percent of Production
Physical Chemical	97.5%
Biological	2.5%

WATER POLLUTION CONTROL EQUIPMENT CAPACITY

In order to aggregate the cost of water pollution control for the steel industry, the amount of treatment capacity installed and in operation must be determined. In this analysis, the capacity of treatment equipment on a process unit which is treated always has the same daily capacity as the production unit. The procedure for determining the amount of treatment equipment in place is separated into two parts below. First, treatment for existing production units is considered. Second, treatment at new production units is determined.

EXISTING PRODUCTION FACILITIES

The amount of productive capacity with water pollution control equipment installed in 1974 was specified by NUS/Cyrus Rice for each subcategory. This treatment coverage ratio was provided for each guideline level and reflects the level of compliance within the industry with guideline standards. As

Exhibit 25 points out, it is assumed that, by definition, 100 percent of the industry was in compliance with the Base treatment level in 1974.[11] For most purposes, the portion of the industry meeting BPCTCA standards was significantly smaller and that portion meeting the stricter BATEA guidelines even smaller. Since treatment levels are incremental, a facility operating BATEA treatment equipment also is operating abatement equipment meeting Base and BPCTCA standards.

For some processes no additional treatment is required above the BPCTCA guideline level in order to meet BATEA standards. For example, in the basic oxygen furnace-semi-wet, batch sulfuric pickling and cold rolling treatment categories, the percent of capacity treated is the same for BPCTCA and BATEA.

In continuous casting, treatment of wastewater is assumed to meet BPCTCA abatement standards in 100 percent of industry facilities. Therefore, both Base and BPCTCA coverage is 100 percent. A smaller percentage meets the BATEA requirements.

Electric furnaces which employ electrostatic precipitators or "semi-wet" methods of air pollution treatment are already operating at BATEA level. Industry coverage at all treatment levels is thus assumed to be 100 percent.

Treatment Capacity In-Place in 1974

The treatment coverage ratios described above and listed in Exhibit 25 are multiplied by the production capacity

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[11] *EPA-440-1-74-024-a, Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the STEELMAKING Segment of the Iron and Steel Manufacturing Point Source Category, June 1974, p. 257.*

for the corresponding processes to determine the treatment capacity in-place in 1974. Where a subcategory includes more than one process, all processes are assumed to have the same treatment coverage ratio. Where a process is treated by more than one subcategory, the portion of production capacity producing each waste stream has the treatment ratio of the corresponding subcategory. Also treatment coverage is assumed to be the same for all sizes of process units.

To illustrate the determination of in-place treatment capacity, the basic oxygen furnace-wet is considered.

BASIC OXYGEN FURNACE-WET
TREATMENT CAPACITY IN-PLACE
AT BPCTCA LEVEL

	Small	Large
Production Capacity in 1974	25.73 million tons	60.54 million tons
Treatment Coverage Ratio	76.0%	76.0%
Treatment Capacity	19.55 million tons	46.01 million tons

Treatment Capacity Increases from 1974 In-Place

Since in-place treatment of most subcategories does not meet BPCTCA or BATEA levels completely, additional treatment must be added. Treatment capacity is added in annual increments to meet each guideline level by the specific compliance date. The rate of progression from the in-place coverage ratio to 100 percent coverage by the compliance date is the same for each process. However, the rate is slower for BATEA since there is a longer period before compliance is required. The following table lists the percent of untreated capacity in 1974 which must be treated in each year.

POLLUTION CONTROL TREATMENT PROGRESSION
FROM 1974 IN-PLACE TO COMPLIANCE

	Guideline Level	
Year	BPCTCA	BATEA
1975	10%	0%
1976	30%	0%
1977	50%	2.5%
1978	80%	7.5%
1979	100%	15%
1980	100%	25%
1981	100%	55%
1982	100%	85%
1983	100%	100%

Source: EPA, Office of Planning and Evaluation

From the table, it can be seen that 10 percent of all capacity which does not meet the standards of BPCTCA level in 1974 must have equipment installed in 1975. No change in BATEA occurs. By the end of 1976, 30 percent of the capacity not treated to BPCTCA level in 1974 must be treated. This is an increment of 20 percent in 1976. The example below exhibits this procedure for basic oxygen furnace-wet.

BASIC OXYGEN FURNACE-WET
TREATMENT COVERAGE RATIO BY YEAR
(percentage)

	Guideline Level	
Year	BPCTCA	BATEA
1974	76.0	8
1975	78.4	8
1976	83.2	8
1977	88.0	10.3
1978	95.2	14.9
1979	100.0	21.8
1980	100.0	31.0
1981	100.0	58.6
1982	100.0	86.2
1983	100.0	100.0

Open hearth furnace production utilized nearly 65 percent of capacity in 1972. However, Environmental Economics Associates projections of basic oxygen and electric furnace production together with the long-term trend in shipments indicate that only 40 percent of open hearth capacity will be utilized by 1983. Since BPCTCA treatment coverage in 1974 was already 70 percent, no further pollution control expenditures were incurred for open hearth furnaces for BPCTCA. However, since BATEA coverage is 0.0 per unit in 1974, it is increased to treat the 40 percent of capacity utilized in 1983.

Effluent limitations guidelines for all processes of the iron and steel point source category were not proposed simultaneously. In this analysis all Phase I capacity placed into service after 1976 meets NSPS requirements while Phase II capacity added after 1977 meets this standard. These dates are after proposal of the guidelines to reflect construction lead times. The cost of compliance with NSPS standards is the sum of BPCTCA and BATEA costs for each process but does not include Base costs.

WATER POLLUTION CONTROL CAPITAL EXPENDITURES

Capital expenditures for water pollution abatement equipment are required to meet each effluent guideline level--Base, BPCTCA, BATEA, and NSPS. The amount of water treatment capacity which must be added in each year is determined as described above. Production capacity requirements are described in Section 2.

The inventory of units used in this analysis consists of a number of small, medium, and large typical units for each process. With this differentiation in size, economies of scale can be computed.

Computation of capital expenditures for water pollution control on each process unit is essentially identical for each level of guideline treatment. All ages and sizes of units are assumed to have the same proportion of treatment. The allocation of production units to water treatment technology alternatives is calculated according to the procedures discussed above. The number of units in each process covered with treatment facilities in any given year is computed from the treatment coverage ratios set forth in Exhibit 24 and discussed in detail above.

Capital expenditures required for water pollution control for each unit are calculated from the equation:

$$Y = AX^B$$

where Y is the amount of capital expenditure required; X is the size of the unit; A is a calculated constant for each guideline level of treatment; and B is a scale constant to account for economies of scale.

Capital expenditures are first computed for each typical size process unit. Then total capital expenditures are computed as the cost per unit times the number of units treated.

CAPITAL EXPENDITURES PER PROCESS UNIT

Capital costs are assumed to have economies of scale, and therefore costs differ for large, medium, and small plants. In the equation:

$$\text{plant cost} = A \times (\text{plant size})^{.6}$$

the factor "A" can be determined by using the detailed costs provided by NUS/Cyrus Rice engineers for the model plant. The capital cost for another size plant is then found by substituting the appropriate plant size into the above equation. Exhibit 26 sets forth the data with which the "A" factor for each water treatment process at each guideline level can be developed. These factors are developed from the capital cost per ton data and the model plant size data set forth in Exhibits 20, 22, 23, and 24. Total capital cost for the model plant is capital cost per ton times model plant size times operating days per year. Capital costs have been inflated to 1975 dollars.

In the case of the basic oxygen furnace-wet, as was discussed above and is recapitulated briefly below, calculation of the "A" factor is as follows:

$$Y = AX^{\beta}$$

where $Y = \$623,607$ in 1975 dollars

$X = 7590$ tons per day model plant size

$B = .6$

therefore

$$623,607 = A\,(7,590)^{.6}$$

$$A = 623,607 \div (7,590)^{.6}$$

$$A = 2,929$$

Using this constant, the following calculations can be made for the large basic oxygen furnace-wet unit using plant information which was provided in the ADL inventory.

BASIC OXYGEN FURNACE-WET
CAPITAL EXPENDITURES FOR WATER POLLUTION
TREATMENT OF A SINGLE UNIT AT BPCTCA LEVEL
(1975 dollars)

	Small Unit	Large Unit
Capacity:	1.61 million tons/year ÷ 365 days/year = 4,400 tons/day	3.78 million tons/year ÷ 365 days/year = 10,400 tons/day
Capital Expenditures for a Single Unit:	$2,929 \times (4,400)^{.6}$ = .45 million	$2,929 \times (10,400)^{.6}$ = $.75 million

CAPITAL EXPENDITURES FOR EXISTING FACILITIES

Total capital expenditures are determined by multiplying the cost per unit times the number of units treated. The number of units treated is determined as described in the previous chapter.

Continuing the example of the basic oxygen furnace-wet, computation of total BPCTCA capital expenditures for equipment in-place in 1974 is described below.

BASIC OXYGEN FURNACE-WET
CAPITAL EXPENDITURES FOR BPCTCA EQUIPMENT
(1975 dollars)

	Small	Large
Number of units	16	16
Percent with "wet" air treatment	65%	65%
Number of units to be treated	10.4	10.4
Percent treated in 1974	76%	76%
Number of units treated in 1974	7.9	7.9
Capital expenditures per unit	$.45 million	$.75 million
Total Capital Expenditures	$3.6 million	$6.0 million
GRAND TOTAL	9.6 million	

The fractional plant unit which appears in the example is quite necessary. The number of typical large plants is determined exactly so that the amount of capacity treated by each method of abatement is correct. This corresponds to a new unit being placed in service for less than a full year.

CAPITAL EXPENDITURES FOR NEW FACILITIES

As discussed above, New Source Performance Standards cover additions to Phase I processes brought on-line after 1976 and additions to Phase II processes after 1977.

Construction expenditures occur for three years before the equipment is in-place and in operation. Since abatement facilities may be completed and brought on-line at any point during the year, on average they are assumed to be finished at mid-year. Therefore, the three-year construction period actually results in capital costs in four calendar years. The spreading of expenditures follows the pattern below:

CONSTRUCTION EXPENDITURES FOR
WATER POLLUTION CONTROL EQUIPMENT
BY YEAR

Year	Percent Expended Calendar Year	Year to Date
Placed in-service	15%	35
1 year prior	35%	35
2 years prior	35%	30
3 years prior	15%	0

The expenditures in current dollars of each year totals the current dollar cost in the year of completion of the facilities. Capital expenditures for new facilities built prior to NSPS requirements are calculated according to the same procedure as NSPS except that the cost per unit is BPCTCA or BATEA depending on which standard must be met.

WATER POLLUTION CONTROL OPERATIONS AND MAINTENANCE COSTS

Operations and maintenance costs are divided into the categories below:

- Operating labor
- Maintenance labor
- Maintenance materials and supplies
- Power
- Chemicals
- Sludge and other waste disposal
- Other

The first three items above were combined into one cost category in the Effluent Guidelines Development Document. For all processes this cost is dependent upon the size of the production unit on which the treatment equipment has been installed. Therefore, costs for the "labor, maintenance materials, and supplies" category are a function of the capital cost for pollution control equipment and reflect economies of scale.

All other operating costs, including power, chemical, disposal costs, carbon column rental, etc., are a function of operating output rather than plant size, and thereby vary with production volume.

As in the calcuation of capital expenditures for water abatement programs, this analysis of operations and maintenance cost has utilized the inventory of steel product units and production volumes described in Section 2.

The examples below set forth operations and maintenance costs for the basic oxygen furnace-wet process at BPCTCA level of control in 1977. These calculations are based on large units which are equipped with wet air pollution abatement equipment. The number of units in this category incurring operations and maintenance costs is as follows:

1977 INVENTORY OF BASIC OXYGEN FURNACE-WET

Number of large units in 1974:	16
Size of a large unit:	3.78 million tons
Capacity added since 1974:	13.9 million tons
Number of new large units:	3.7 million tons
Total number of large units:	19.7 million tons
Number of units with "wet" air treatment (65%):	12.8
Number of "wet" units at BPCTCA level (100% compliance in 1977):	12.8

Computation of operating expenses on all process units is essentially identical for each level of guideline treatment; only the cost per unit differs. All ages and sizes of units are assumed to have the same proportion of treatment. To expand on the example below to determine total operating costs for the entire basic oxygen furance process, similar calculations must be made for semi-wet as well as wet units; for small units as well as large; for all guideline levels of treatment including Base, BATEA and NSPS as well as BPCTCA.

OPERATIONS AND MAINTENANCE LABOR

Labor hours required to operate and maintain water pollution treatment equipment vary by plant size. Labor cost is calculated as a function of capital cost in which accommodation for economies of scale due to plant size have been made. As mentioned previously the cost of the "labor, maintenance materials, and supplies" category was furnished by NUS/Cyrus Rice as one item based on 3.5 percent of capital costs. It is further assumed that 80 percent of this total is attributable to labor expenses. The determination of labor costs and labor hours required for the basic oxygen furnace-wet is therefore:

BASIC OXYGEN FURNACE-WET
LABOR REQUIREMENTS AT
BPCTCA LEVEL OF TREATMENT IN 1977

(current dollars)

Capital cost for a large unit (1975 $):	$.75 million[1]
"Labor, maintenance materials and supply" cost per unit (1975 $):	$26,250
Labor cost escalation factor:	1.196
Labor, maintenance materials and supplies per unit (1977 $):	$31,400
Total labor cost per unit:	$25,100
Labor cost per hour:	$13.04[2]
Total labor hours usage per unit:	1,925 man-hours/ year
Number of "wet" units covered at BPCTCA level in 1977:	12.8 units
Total labor cost:	$.32 million
Total labor hour usage:	24,640 man-hours/ year

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[1] *See Section 2 for calculation of capital expenditures.*

[2] *See Exhibit 9 for prices of resources.*

MAINTENANCE MATERIALS AND SUPPLIES

As in the case of labor costs, the maintenance materials and supply requirements associated with water treatment equipment at a unit are dependent on the size of that facility, not the volume of output treated. Costs are assumed to be the remainder or 20 percent of the "labor, maintenance materials, and supply" cost category. As in the calculation of labor costs, basing materials and supply costs on capital expenditures thus implicitly scales costs for plant size variance. No unit of usage of maintenance materials and supplies is available and therefore costs only are calculated below.

BASIC OXYGEN FURNACE-WET
MAINTENANCE MATERIALS AND SUPPLY REQUIREMENTS
AT BPCTCA LEVEL OF TREATMENT IN 1977

(current dollars)

Total "labor, maintenance materials, and supply" cost per unit:	$31,100
Total maintenance materials and supply cost per unit:	$6,200
Number of "wet" units covered at BPCTCA level in 1977:	12.8 units
Total maintenance materials and supply cost:	$79,000

POWER COST

Energy costs related to the operations of water pollution treatment equipment are totally expenditures for electric power. No other fuel is assumed to be used directly. Natural gas and/or other fuels might be used at a steel facility in on-site generation of electric power; however, in this case, the costs of purchasing such energy resources would be allocated to that ancillary process rather than to the production process using the electricity.

Steam is consumed by treatment facilities on coke oven batteries. All steam requirements are internally generated, however, by steelmaking process units, and thus purchase is not necessary.

The amount of power required to treat effluent flows from all processes is set forth in Exhibit 27. Kilowatt-hour usage per ton of product has been broken down by guideline level. These figures were developed from cost data provided by NUS/Cyrus Rice engineers for the model plant technologies at a charge of $75 per horsepower year of $.01145 per kwh in 1972 constant dollars. Based on current knowledge of electric utility rates and conforming with data gathered on power rates paid by major steel companies, TBS determined that this cost was actually lower than the national average. Therefore, electrical usage was priced by TBS at a revised charge of $.014 per kwh used in 1972 dollars.

The cost of energy usage in all processes at all levels of water treatment is a function of productive output from that process. For every incremental ton of steel product, greater flows of effluent to be treated are generated. The cost of power required to run the treatment equipment increases directly.

An example of the calculation of energy cost and usage for the basic oxygen furnace-wet process is typical of this operating expenditure for all processes:

BASIC OXYGEN FURNACE-WET
POWER REQUIREMENTS AT
BPCTCA LEVEL OF TREATMENT IN 1977
(current dollars)

Power consumption per unit:	1.194 X 10^6 kwh[1]
Power cost per kwh:	$.0241 per kwh[2]
Power cost per unit:	$.029 million
Number of "wet" units at BPCTCA level:	12.8
Total power cost:	$.368 million
Total power usage:	15.283 X 10^6 kwh

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[1] *See Exhibit 9.*

[2] *See Exhibit 9.*

CHEMICALS/WASTE DISPOSAL/ OTHER COSTS

The remaining categories of operating and maintenance expense are functions of productive output of steel tonnage. No data on quantity of chemicals used per ton, amount of sludge hauled away per ton, etc. are available. Cost figures for the model plant for each process were developed and provided by NUS/Cyrus Rice engineers. From these, TBS calculated the cost per ton to be applied to all process units in the corresponding subcategory.

An example of the calculation of chemical costs for the basic oxygen furnace-wet process is typical for all processes:

BASIC OXYGEN FURNACE-WET
CHEMICAL REQUIREMENTS AT BPCTCA
LEVEL OF TREATMENT IN 1977

Chemical cost per ton:	\$.0726[1]
Size of a large unit:	3.78×10^6 tons
Chemical cost per unit:	\$.274 million
Number of "wet" units at BPCTCA level:	12.8
Total chemical cost:	\$3,507 million

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[1] *Chemical cost as set forth in Exhibit 5 for basic oxygen furnace-wet at BPCTCA level of treatment is \$.050 in 1972 dollars. Inflated to 1977 dollars, this figure is \$.0726 per ton; see Exhibit 10 for inflation factor reference.*

Disposal of sludge, oil, and pickle liquor wastes is also dependent on the volume of steel produced. NUS/Cyrus Rice engineers estimated the cost of sludge removal varied from \$3 to \$4 per ton of sludge (in 1971 dollars) depending upon the process. This cost, as well as oil and pickle liquor disposal costs, is primarily labor costs associated with the contract hauling of the wastes. In the basic oxygen furnace-wet example, sludge alone is disposed of and only at Base level of treatment. The cost in 1977 per ton of raw steel produced will be \$.0755. Calculation of total waste disposal cost is done in exactly the same fashion as the chemical cost example. No other maintenance and operating expenses are incurred during treatment of basic oxygen furnace wastewaters.

4. AIR POLLUTION CONTROL COSTS

Air pollution in the steel industry results primarily from the Phase I iron and steelmaking processes, not the subsequent forming and finishing processes. The air flow resulting from each process is of course different in volume and emissions content. Thus, treatment costs are determined independently for each process.

The cost of air pollution abatement is incremental to the cost of steel production: costs of other, possibly related, government regulations such as OSHA are not included. This analysis considers only those costs associated with removal of particulate emissions except for removal of sulfur from coke oven emissions.

This section begins with descriptions of the air pollution abatement regulations and the methods used to control particulate air polllution. Subsequent parts of this section explain the source and development of air pollution control cost parameters and their use by TBS in estimating the cost of air pollution control.

AIR POLLUTION ABATEMENT REGULATIONS

Air pollution abatement regulations were developed in a different manner from water pollution control regulations. The Clean Air Act Amendments of 1970 (PL 91-604, hereafter referred to as the Air Act) mandated a series of steps to be taken by States and EPA which would result in attainment of clean air. Within three months of the date of the Act's enactment (December 31, 1970), EPA was required to establish National Ambient Air Quality Standards (NAAQS) for specific pollutants (particulate matter and sulfur oxides are two of these criteria pollutants which are emitted in great quantities by steel mills) which were protective of health and welfare. Then within nine months of the establishment of the NAAQS, States were required to develop regulations limiting emissions from air pollution sources which, when complied with, were calculated to result in the attainment of the NAAQS in the surrounding area. EPA was then given six months to approve or disapprove these State plans. When a State regulation was approved, it become enforceable under Federal law as well as by the State agency. Where portions of the State regulations were disapproved, EPA gave States the opportunity to remedy deficiencies and where corrective action had not been taken by States proposed and promulgated Federal requirements.

The Air Act also required that these regulations be enforced such that the health related NAAQS goals were achieved within three years. Since nearly all State emission limitations were approved on May 31, 1972, June of 1975 was the date for attainment of the primary NAAQS for most areas of the country (excluding some areas where Federal regulations needed to be promulgated, one or two year extensions were granted to States upon plan approval, or litigation by industry delayed the establishment of Federally approved regulations). In general, most heavily industrialized areas containing steel mills have yet to achieve the primary NAAQS.

Because these State Implementation Plans (SIPs) contain varying emissions limitation requirements, different equipment may be required for a particular steelmaking process depending upon where it is located. This different equipment of course implies different costs to control air pollution depending upon location.[1]

AIR POLLUTION CONTROL METHODS

Airborne pollutants generally emanate from a single area of a steel process operation. For example, in steelmaking furnaces the major source of airborne pollutants is from the opening of the furnace vessel. These emissions are frequently gathered for subsequent removal from the air by placing a hood or canopy over the vessel and drafting a flow of air from the vessel through the hood to the treatment equipment.

Air pollution control costs are divided in this study into stack emissions, fugitive emissions, and ancillary facilities. While not all processes have a "stack" in the sense of many industries, this category includes the primary collection point. For example, stack includes the hood over a basic oxygen furnace. Fugitive emissions include all emissions related to a process which are not captured by the primary collection equipment. Ancillary facilities refers to on-site steam boilers.

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[1] *The cost of NSPS control has not been included in this analysis as the promulgation of regulations for each process is scheduled to continue until 1985. Information on cost parameters was available at the time of the study for only one process, electric furnaces, and these data were not final. New facilities in this analysis are required to add stack and fugitive emissions controls.*

The air pollution control treatment equipment used by the steel industry for removal of particulate emissions is of three types: fabric filters, venturi scrubbers, and electrostatic precipitators. In a fabric filter, or baghouse, the air drawn from the process is blown through fabric bags which retain a very high percentage of the airborne pollutants. In principal, this system works just like a home vacuum cleaner. The dust collected in the fabric bags is then removed for subsequent disposal. Venturi scrubbers rely on water to moisten the airborne pollutants and cause them to separate from the air stream. Thus pollutants removed from the air are contained in a stream of wastewater which must then be treated as described in Section 3, Water Pollution Control Costs. The third type of treatment equipment used is the electrostatic precipitator (ESP). This technique works by ionizing the airborne pollutants with an electrical charge and then attracting them to a collection point with the oppostite charge. Water is sometimes sprayed into the air stream both to cool it and to improve the efficiency of the treatment equipment. When this technique is used, a wastewater stream is generated and must be treated.

Since neither federal law nor EPA regulation states which type of treatment equipment must be used for each process, individual steel firms make their own decisions based upon SIP requirements, costs, and availability. Therefore, any type of air pollution control equipment may be found on different units of a given production process.

In addition to the primary collection of airborne pollutants described above, other pollutants may emanate from a process. For example, when a basic oxygen furnace is tilted to pour the molten steel into the teeming ladle, pollutants may become airborne and escape the hood over the vessel. Such airborne pollutants are sometimes referred to as fugitive emissions.

Fugitive emissions may be of low concentration; and where treatment is required, the emissions can be collected by several methods. For example, a large canopy may be placed over the area near the process unit allowing air near the unit to be withdrawn for treatment. Another method would involve evacuating the air from the entire building which houses the process. In either event, the large volume, low temperature, and low pollutant concentration levels for fugitive emissions suggest that fabric filters will likely be used to treat the resulting air stream.

AIR POLLUTION CONTROL COST PARAMETERS

Due to the varying and complex standards set by individual states, no engineering cost analysis of compliance based upon equipment specified for each state has been performed. In the area of new source standards, states may supersede EPA standards with more stringent controls. Hence, as with the existing source costs, there is a lack of precise cost data for new source standards.

The 1974 Cost of Clean Air report prepared for EPA by Battelle Columbus Laboratories has been used as the basis for projecting cost impacts for stack emissions requirements.[2] Unlike water pollution control costs which were based on a specific treatment model, Battelle cost estimates are based on published data for equipment with varying specifications.

Engineering cost estimates for equipment to meet fugitive emission standards were supplied by the EPA Standards and Cost Analysis Branch in Durham, North Carolina. These cost estimates relied upon ADL engineering cost equations and air flow rates estimated by EPA.

STACK EMISSION CONTROL COST PARAMETERS

Air pollution control cost data from the Cost of Clean Air are not based upon specified equipment from which observations of pollutant removal and cost determinations were made. Rather, the costs are based upon published data and industry sources. Therefore, it is unclear whether the equipment considered will meet required limitations.[3] Annual costs were divided into individual components such as labor, energy, and supplies through use of the 1969 Battelle study of air pollution control in the steel industry. Costs contained in the Cost of Clean Air omit some processes which probably require air treatment. For example, no costs were included for the following:

- Acid mist from pickling
- Hot scarfing

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[2] *Some engineering data reported in the 1974 Cost of Clean Air and used herein were obtained from A Systems Analysis of the Integrated Iron and Steel Industry, Battelle Columbus Laboratories, 1969.*

[3] *EPA has recently requested proposals for a study which would increase the information available on air pollution control cost parameters.*

- Ancillary facilities
- Coal handling

The costs selected for this study represent minimum acceptable standards. Additional costs to meet more stringent SIPs have not been included. This simplification is necessary for two reasons. First, comprehensive engineering cost estimates are not available for each state. Second, there is no publicly available complete inventory of steel facilities by state.

The cost of controlling fugitive emissions was determined by EPA Office of Air Quality Planning and Standards.[4] As with stack emissions, comprehensive engineering cost analysis has not been performed by EPA for fugitive emissions. It was, however, determined that the cost relationships based upon air flow in the ADL report appeared to be reasonable. Therefore, the cost equations presented by ADL were adopted by EPA. However, independent estimates of air flow required to control fugitive emissions were developed by EPA.

The cost of air pollution control for ancillary facilities, on-site power generation, was determined from the TBS study Economic Analysis of Effluent Guidelines; Steam Electric Power Plants, December 1975.

Data on existing air pollution abatement equipment installed was obtained from the plant inventory in the Cost of Clean Air, Appendix C. Estimates regarding the type of air pollution abatement equipment which will be installed by 1978 to achieve full compliance were obtained from EPA/SEAS (Strategic Environmental Assessment System). These treatment percentages are listed in Exhibit 28.

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[4] *Obtained from the Standards and Cost Analysis Branch of EPA.*

STACK EMISSIONS CONTROL COSTS

Capital expenditures for stack emissions control were obtained directly from the 1974 Cost of Clean Air, Appendix C. The treatment level selected was "Federal Standard" where provided. For processes where this was not available, for example coke ovens, the data available were accepted as representing the "Federal Standard." This level of treatment was taken to represent the minimum acceptable standard. More stringent control ascribable to SIPs was not included.

Separate cost relationships were developed for each type of pollution treatment equipment for each production process. Thus for the basic oxygen furnace, cost relationships were developed for high energy scrubbers and electrostatic precipitators. No costs were available for fabric filters and no furnaces used this type of treatment. Separate cost relationships were developed for capital expenditures, and each category of operations and maintenance--labor, electric power, and maintenance.

Capital Expenditures

Capital expenditures data for each process were fit to an equation of the form $Y=AX^B$ where,

Y = *Investment cost*

X = *Capacity of process unit*

B = A scale constant to account for non-linearity of cost with size

A = Calculated from data in the Cost of Clean Air 1974

If data were provided for only two size process units, the values of A and B were determined by solving the two resulting equations in two unknowns.

For treatment types where cost data for three or more size process units were provided, the cost relationship was determined by regression. The equation above is linear in its logarithm form. Thus $\log Y = A + B \log X$ has the familiar form of $e = d + mc$. The data for each unit size were calculated in this form, and a least squares regression was performed.

The resulting capital expenditure cost relationships are tabulated in Exhibit 29.

Operations and Maintenance Costs

Since annual costs in the 1974 Cost of Clean Air do not provide detail by type of cost, data from the 1969 study A System Analysis of the Integrated Iron and Steel Industry, by Varga et. al, were used. These same relationships were used by Battelle Memorial Institute in calculating annual costs for the Cost of Clean Air.

Labor was calculated from the relationship of man-hours per year to size of unit. Since significant economies of scale are possible in labor, the data were fit to an equation of the form $Y = AX^B$ as above. Data for three size units were available for each process and treatment combination.

Therefore, the relationship of man-hours to capacity was determined by regression of the logarithmic form of the equation as described above.

Labor costs were determined by multiplying the man-hours derived from the relationship above times the hourly cost for the appropriate year.

Electric power was calculated from the relationship of kilowatt-hours per year to size of unit. The same procedure described above was used to fit power consumption to an equation of the form $Y = AX^B$.

Maintenance costs including supplies were estimated in the Varga study in 1969 dollars. These costs were first adjusted to 1972 dollars by use of the GNP inflation factor. The relationship of these costs to size was then developed as above based upon the form $Y = AX^B$.

The cost relationship developed for each of these cost elements can be determined from the A and B parameters listed in Exhibit 30.

FUGITIVE EMISSIONS CONTROL COSTS

The costs for fugitive emission control were developed by the EPA. These costs rely upon the equations estimated by Arthur D. Little in its study for the AISI. However, several parameters were modified. These modifications are summarized below:

- Not all units which require control of fugitive emissions require the building evacuation proposed by ADL in its study for the AISI. For the purpose of cost estimating, those not requiring building evacuation were assumed to require a canopy.

- The costs estimated by ADL for fugitive emissions are correct for the air flows assumed.

- Units which require fugitive emission control by canopy require an air flow of 30 percent of the amount estimated by ADL using building evacuation.

- EPA estimates of air flow requirements for control of fugitive emissions are summarized in the table below.

- Specific estimates of control costs for coke ovens were provided.

Fugitive emission control costs are based upon use of fabric filters for treatment of the air flow. The air flow in standard cubic feet per minute (SCFM) assumed for each process is listed in the table below:

FUGITIVE EMISSION CONTROL
AIR FLOW ESTIMATES

	SCFM	
Process	Building Evacuation	Canopy
Sinter Strand	n/a	1.5 @ 25,000 ea.
Blast Furnace	500,000	150,000
Open Hearth Furnace	n/a	300,000
Basic Oxygen Furnace	1,000,000	300,000
Electric Arc Furnace	1,000,000	300,000

n/a = not applicable
Source: EPA

The cost for treatment of each level of air flow is determined according to the equations contained in the ADL report.[5] The costs for each item for each process are presented in Exhibit 31.

AIR POLLUTION CONTROL EQUIPMENT CAPACITY

The inventory of units for each production process used in this study is based upon a study by ADL for the AISI. A summary description of the facility inventory is contained in Section 2 and Exhibits 15, 16, and 17.

STACK EMISSIONS COSTS

Stack emissions are assumed in this study to emanate only from the five processes listed below:

- Sinter
  - --Strand
  - --Windbox[6]
- Coke oven
  - --Pushing[6]
  - --Charging[6]
  - --Desulfurization
- Open hearth furnace
- Basic oxygen furnace
- Electric arc furnace

Percent of Capacity Treated. The first step in determining air pollution control equipment capacity is to specify

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[5] *ADL report, pages B-17 and B-18.*

[6] *These emissions are considered by some observers to be fugitives. However, due to data limitations, they were included in stack emissions.*

the amount of capacity for each process which is treated by each type of air pollution control equipment. This is done in two steps. First, the treatment in-place in 1974 was derived from the 1974 Cost of Clean Air inventory of units and treatment type. These percents are tabulated in Exhibit 28. Then the percent treated in 1974 was increased in equal increments each year so that 100 percent of the installed capacity was treated by the end of 1978. The mix of treatment types in 1978 was assumed to be that provided by EPA/SEAS. These percents are also tabulated in Exhibit 28. Following 1978, the percent treated by each type of pollution control is held constant.

The table below illustrates these computations for the basic oxygen furnace. It should be noted that the decrease in relative treatment by venturi scrubbers was accomplished by adding new capacity as electrostatic precipitators until the specified relationship was obtained. Existing venturi scrubbers were not removed.

BASIC OXYGEN FURNACE
PERCENT OF CAPACITY TREATED FOR STACK EMISSIONS

	Electrostatic Precipitators	Venturi Scrubbers	None
Percent treated in			
• 1978	66.1%	33.9%	0%
• 1974	46.8	51.7	1.5
Difference in percent treated	19.3	-17.8	
Annual increment	4.82	-4.45	
Percent treated by year			
• 1975	51.6	47,2	
• 1976	56.4	42.8	
• 1977	61.3	38.4	
• 1978	66.1	33.9	

The single exception to this procedure is open hearth furnaces. Since the present treatment level of 80 percent exceeds the estimate of open hearth capacity in operation in 1983, no increase in treatment of open hearth furnaces occurs.[7]

Some processes, such as sinter and coke ovens, have major components which require different treatment types. This was accomplished by treating each major component, such as sinter strand and windbox, as if they were separate processes. The percent of each process treated by each type of equipment is displayed in Exhibit 32.

Amount of Capacity Treated. The amount of capacity already treated in 1974 is calculated as the percent treated in 1974 times the capacity installed in 1974. The percent treated in each year can be calculated as described above. The production capacity installed is calculated as described in Section 2. For the basic oxygen furnace, the amount of capacity treated would be calculated as shown below:

BASIC OXYGEN FURNACE
AMOUNT OF CAPACITY TREATED IN 1974
BY ELECTROSTATIC PRECIPITATORS

Capacity	86.26 million tons
Percent Electrostatic Precipitators	46.8 percent
Amount treated by Electrostatic Precipitators	40.37 million tons

All units are assumed to have installed treatment in the same proportion regardless of age and size.

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[7] *NUS/Cyrus Rice estimates 36 percent of open hearths operating in 1972 will still be operating in 1983.*

FUGITIVE EMISSIONS

Fugitive emissions are assumed in this study to emanate from the five processes listed below:

- Sinter strand
- Coke ovens
- Blast furnace
- Open hearth furnace
- Basic oxygen furnace
- Electric arc furnace

Percent of Capacity Treated. This study assumes that no fugitive emission control systems were installed prior to 1975. Furthermore, it is assumed that fugitive emission control systems will be installed in even increments from 1977 to 1980.[8] Thus one-third of the existing facilities in each year will have equipment installed to control fugitive emissions. Because no facilities have existing control equipment, the procedures required to compute the incremental treatment in each year are not complicated as they were for stack emissions.

Amount of Capacity Treated. As is done for stack emissions, the amount of capacity treated in each year for fugitive emissions is determined by multiplying the percent treated times the capacity installed. The production capacity is calculated as described in Section 2.

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[8] *EPA Office of Planning and Evaluation.*

Applying this procedure to the basic oxygen furnace produces the results below:

CAPACITY TREATED FOR FUGITIVE EMISSIONS
BASIC OXYGEN FURNACE
IN 1978

Number of units	36.6
Capacity	103.8 million tons
Percent treated	33.3 percent
Capacity treated	34.6 million tons
Number of units treated	12.2

The number of fugitive emissions control devices required for the capacity treated is determined by the procedure described by ADL[9] and summarized in the table below:

NUMBER OF FABRIC FILTER UNITS
REQUIRED TO TREAT FUGITIVE EMISSIONS

Process	Number of Units
Sinter	direct count
Blast Furnace	direct count
Open Hearth	3.41 (capacity in millions of tons per year)
Basic Oxygen Furnace	direct count
Electric Arc Furnace	2.44 (capacity in millions of tons per year)$^{2/3}$

Source: ADL report

The number of fugitive control devices required for a basic oxygen furnace is determined by direct count. The number of process units is determined as described in Section 2 and the number treated in a year by multiplying the number of process units times the percent treated.

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[9] *ADL report, page B-10.*

The number of units treated must be further broken down into the number treated by building evacuation or canopy. Using the percent of each presented in the table below, 90 percent of basic oxygen furnaces would be treated with canopies and 10 percent with building evacuation. Multiplying these percentages by the capacity treated in the example above results in 1.2 units by building evacuation and 11.0 units with canopies.

TYPE OF CONTROL REQUIRED FOR
FUGITIVE EMISSIONS

	Percent Controlled	
Process	Building Evacuation	Canopies
Sinter Strand	0	100
Electric Furnace	50	50
Open Hearth	0	100
Basic Oxygen Furnace	5	95
Blast Furnaces	10	90

Source: EPA

AIR POLLUTION CONTROL CAPITAL EXPENDITURES

Air pollution control capital expenditures are determined by multiplying the amount of capacity treated in a year by the cost of the pollution control equipment adjusted for inflation.

The cost of air pollution control equipment is not incurred entirely in the year it is placed into service. To most closely approximate normal engineering and construction lead times, the cost of air pollution control equipment is spread over three years. Since equipment may be installed at any time during the year, it is assumed to be installed on average at mid-year. Therefore, expenditures spread over three years are incurred in four calendar years. The proportion spent in each year is listed below:

PROPORTION OF AIR POLLUTION CONTROL
CAPITAL EXPENDED PRIOR TO INSTALLATION

Year	Actual Years	Calendar Years
Placed into service	30	15
1st year prior	40	35
2nd year prior	30	35
3rd year prior	0	15

STACK EMISSIONS

The capital expenditures required for removal of particulates from stack air streams for each unit are calculated from the equation:

$$Y = AX^B$$

where Y *is the capital expenditure required*

X *is the size of the unit*

A *and* B *are parameters derived as described earlier in this section.*

The parameters A and B for each air pollution control treatment type for each process are listed in Exhibit 29.

Capital expenditures for large basic oxygen furnaces treated with electrostatic precipitators are calculated in the table below:

CAPITAL EXPENDITURES IN PLACE IN 1974
BASIC OXYGEN FURNACE
AIR POLLUTION CONTROL WITH ELECTROSTATIC PRECIPITATORS
(1975 dollars)

Size of a large unit (X)	3.78 million tons
Parameter A	364.7
Parameter B	.689
Capital expenditures per large unit ($Y=AX^B$)	$12.4 million
Number of large units	16
Percent treated with ESP	46.8 percent
Number of large units treated with ESP	7.5
Capital expenditures for units treated with ESP	$93 million

Total capital expenditures for existing treatment of basic oxygen furnaces are determined by following the above procedure using the parameters for venturi scrubbers from Exhibit 29. Then the procedure is reported for small units with ESP, then Venturi scrubbers, and finally, all categories are summed. Capital expenditures for other processes are calculated in the same manner.

Capital expenditures for new facilities and additional treatment of existing facilities are determined according to the same general procedure. The amount of treatment added to existing facilities is the increment to the percent treated for that year times the existing capacity. The number of new units is determined as described above. The total number of new units for each process follows from the cumulative percent treatment which applies in the year.

As previously noted, the fractional plant which appears in the example above is very necessary. The number of typical large plants is determined exactly so that the amount of capacity treated by each type of treatment is correct. This also reflects the fact that new productive units, hence pollution control devices, will not be brought on-line until scale economies can be realized.

Fugitive Emissions

Exhibit 31 contains the capital expenditures required for each unit of fugitive emission control on each production process. These amounts were derived from the air flows provided by EPA and the equations in Appendix B of the ADL report. The cost in 1972 dollars was adjusted to 1975 dollars using Exhibit 10.

The capital expenditures in any year are computed by multiplying the number of fugitive emission control units times the 1975 cost adjusted for inflation. An example for the basic oxygen furnace is presented below:

CAPITAL EXPENDITURES FOR FUGITIVE EMISSIONS CONTROL EQUIPMENT
BASIC OXYGEN FURNACE
IN 1978

	------Duct Type-----	
	Building Evacuation	Canopy
Cost per unit in 1975	$ 8.54	$3.42 million
Inflation factor	1.225	1.225
1978		
Cost per unit	$10.46	$4.19 million
Number of units treated	1.22	10.98
Cost per duct type	$12.76	$46.01 million
TOTAL COSTS	$58.77 million	

The same procedure is used for each process in each year to determine the total amount of capital expenditures for pollution control. The cost of equipment placed into service in any year is spread into the three prior years in the same manner as costs for stack emission control.

AIR POLLUTION CONTROL OPERATIONS AND MAINTENANCE COSTS

Operations and maintenance (O&M) costs include categories for electric power, labor, maintenance and miscellaneous (or other). The computation of each category is described below.

STACK EMISSIONS

The method of computing each category of O&M costs is the same for stack emissions. Consumption of each category is determined according to the equation below:

$$Y = AX^B$$

where Y *is the consumption in units or dollars*

X *is the size of the process unit in tons per year*

A *and* B *are parameters from Exhibit 30*

Miscellaneous O&M costs for stack emissions are included in Maintenance.

The cost of each O&M category for large basic oxygen furnaces using electrostatic precipitators is calculated in the following example:

LARGE BASIC OXYGEN FURNACE
OPERATIONS AND MAINTENANCE COSTS IN 1975
FOR ELECTROSTATIC PRECIPITATOR

(1975 dollars)

Size of unit	3.78 million tons
Number of large units	16
Percent treated with ESP in 1974	51.6 percent
Number treated with ESP in 1974	9.8
Power	
Power consumption per unit	$1.86\ (3.78\text{ million})^{1.136}$ or 55.2 million kwh
Cost per kwh*	\$.0215 per kwh
Power cost per unit	\$1.19 million
Total power cost	\$11.66 million
Labor	
Labor use per unit	$.7\ (3.78\text{ million})^{.626}$ or 9130 manhours
Cost per manhour*	\$10.62
Labor cost per unit	\$96,960
Total labor cost	\$.95 million
Maintenance	
Maintenance cost per unit	$1.2\ (3.78\text{ million})^{.817}$ or \$283,787
Total maintenance cost	\$2.78 million

See Exhibit 9.

As in the case of capital expenditures, total operations and maintenance costs in a year are computed by repeating the procedure above for each size unit, process, and treatment type.

It should be noted that where capital expenditures in a year are based upon the increase in treatment of existing facilities and treatment of new facilities, operations and maintenance costs are for all installed treatment. Therefore, the percent treated is not the annual increment, but the sum of initial treatment and annual increments to date.

FUGITIVE EMISSIONS

O&M costs for each process are computed by multiplying the number of fugitive emission control units installed by the cost per unit. The O&M cost per unit is computed using the parameters shown in Exhibit 31 and inflation factors from Exhibit 10. An example for the basic oxygen furnace is presented below:

OPERATIONS AND MAINTENANCE COSTS FOR BASIC OXYGEN FURNACE FUGITIVE EMISSIONS IN 1978

(current dollars)

	------Duct Type------	
	Building Evacuation	Canopy
Number of units treated	1.22	10.98
Labor		
Manhours per unit	78,840	23,651
Cost per man-hour	$14.16	$14.16
Labor cost per unit	$ 1.12	$.33 million
Labor cost	$ 1.37	$3.62 million
TOTAL	$4.99 million	
Power		
kwh per unit	24.4	7.32 million kwh
Cost per kwh	$.0254	$.0154
Power cost per unit	$.62	$.19 million
Other cost	$.76	$2.09 million
TOTAL	$2.85 million	
Miscellaneous		
Cost per unit 1975	$191,100	$57,300
Inflation to 1978	1.205	1.205
Cost per unit 1978	$230,200	$69,100
Miscellaneous cost	$ .28	$.76 million
TOTAL	$1.04 million	
Maintenance		
Cost per unit in 1975	$.43	$.17
Inflation to 1978	1.205	1.205
Cost per unit in 1978	$.52	$.20 million
Maintenance cost	$.63	$2.20 million
TOTAL	$ 2.83 million	
GRAND TOTAL	$11.71 million	

ANCILLARY FACILITIES

Ancillary facilities are primarily on-site power generation. Treatment costs for ancillary facilities were determined using the 1974 TBS study, Economic Impact of Effluent Guidelines on Steam Electric Power Plants. Thus, the unit cost of treating steam power generation units in the steel industry was assumed to be the same as comparable units in the electric utility industry.

The costs used were $113.6 capital investment and $.0026 of operating and maintenance costs per kilowatt-hour used. These treatment facilities were placed in service in uniform amounts for each year from 1975 through 1983.

5. FINANCIAL ANALYSIS METHODOLOGY

The financial analysis module of PTm(Steel) is designed to calculate the revenues required by the industry for normal operations and the external financing needed to meet projected capital expenditures and other uses of funds. To do this, the module constructs an industry income statement and flow of funds statement for each year of the analysis. The income statement is developed by initially calculating the dollar return to equity at the rate specified. The remainder of the statement is then constructed in reverse order from this item, using operations and maintenance costs, depreciation, net interest expenses and income, property and sales taxes which are already computed. Revenue requirements are the sum of all these costs, including a return to equity. The flow of funds is developed by totaling the uses of funds in a given year, which include capital expenditures, changes in construction work in progress, increases in working capital, and refundings of long-term debt to arrive at total required funds. This requirement is then met as far as possible by internal sources; namely, depreciation and retained earnings, with the balance made up of external issues of long-term debt and common stock. The logic of these calculations is displayed in Exhibits 32 and 33, and the details are described below. Exhibits 34 and 36 present actual financial statements for 1977 as generated by PTm(Steel).

All calculations within the financial analysis module of PTm(Steel) are computed in current dollars. During periods of inflation, these financial transactions recognize cost escalation where relevant (i.e., operations and maintenance expenses) as well as the historic cost basis of such charges as depreciation and refundings of long-term debt. The cost escalation factors used are displayed in Exhibit 10 of this volume. For comparability, all financial data projected by PTm(Steel) and contained in Volume I have been reported in 1975 dollars.

THE INCOME STATEMENT

In general, an income statement can be projected in two ways. The most common method is to subtract projected expenses from projected revenues to arrive at a figure for net income. This technique requires that both revenues and expenses be forecast in advance, and is useful for examining short-term changes in net income and return on equity. An alternative method consists of calculating the net income that will be required in each future period and adding to this figure the projected expenses to arrive at a projection of required revenue. This second method is the most useful for analysis of the price and revenue impacts of increased costs and capital expenditures, and is particularly valid over the long term when economic behavior will be driven by an attempt to recognize a targeted average return on equity. In other words, over the long term we would expect revenues to be adjusted to meet increased expenses and to provide the targeted return to the industry's stockholders.

PTm(Steel) uses the second method to construct a steel industry income statement for each year of the analysis. The model begins by calculating the required net income for the particular year, which is the specified return on equity multiplied by the stockholders' equity in the industry, averaged over the previous and current year. Stockholders' equity in any year is calculated as the sum of the previous year's equity plus the current year's retained earnings, and any issues of stock which have been required during the year. Income taxes, both state and federal, are calculated next from the required net income, and interest charges are calculated based on the amount of long-term debt outstanding. Knowledge of these two charges plus the required return allows the computation of required earnings before interest and taxes (EBIT). Depreciation charges are calculated along with property taxes, and then all expenses are added to EBIT along with the operating and maintenance charges for production and pollution control equipment. Finally, sales taxes are calculated and added to the total, which is the required revenues for operation of the industry. Each of these steps will be explained in more detail below.

RETURN ON EQUITY

The required return on equity used in this analysis was developed from historical data. The nominal industry return on equity for each of the years 1965 to 1974 was calculated from the Annual Statistical Reports of the AISI. These returns were then adjusted for inflation to yield a "real" return on equity. This adjustment was performed by subtracting each year's percentage change in the GNP deflator[1] from that year's return on equity. For example, in 1972 the return on equity as calculated from AISI data was 5.8 percent, and the change in the GNP deflator in that year was 3.4 percent. Thus the "real" or above-inflation return on equity was 2.4 percent. The average real return on equity for the period was 3.5 percent.

The average real return on equity computed above was used along with projections of inflation to develop the required nominal return on equity for each year from 1975 to 1985. Return

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[1] *Source: Economic Report of the President, 1975*

on equity figures for each of these years were calculated by summing each year's projected percentage change in the GNP deflator[2] and the average real return of 3.5 percent to arrive at that year's required return. For example, in 1977 the GNP deflator is expected to increase by 6.5 percent, which implies that the required nominal return on equity in 1980 will be 10.0 percent. The full schedule of required returns calculated by this method and input to PTm(Steel) is displayed in Exhibit 36. The actual returns on equity were input to PTm(Steel) for 1972, 1973, and 1974.

REQUIRED NET INCOME

Using the nominal returns on equity described above, PTm(Steel) computes the required net income for each year of the analysis. For example, if the 1976 total stockholders' equity is $16.8 billion and the 1977 total stockholders' equity is $17.9 billion, the required net income in 1977 would equal $1.7 billion. This figure results from multiplying the average total equity for 1976 and 1977 times the specified return on equity for 1977. These calculations are shown below.

CALCULATION OF REQUIRED NET INCOME
(billions of current dollars)

	1976	1977
Stockholders Equity		
• Current	$16.76	$17.87
• 2-Year Average		17.32
Required Rate of Return		9.95%
Required Net Income		$1.72

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[2] *Source: Chase Econometrics, Inc. forecasts provided to the EPA*

INCOME TAXES

State and federal income taxes are calculated as a percent of net income in each year and are computed using average effective state and federal tax rates for the industry. Effective tax rates were used due to the lack of adequate plant data which prevented calculation of taxes using nominal tax rates and deferrals. Both of these rates are inputs to PTm(Steel), and for this anlaysis, 7.6 percent is used as the state income tax rate[3] and 26.1 percent is used as the federal income tax rate.[4] Each of these rates is held constant from 1972 to 1985. With knowledge of the required net income and the income tax rates, required earnings before taxes (EBT) is calculated by dividing the required net income by the factor (1.0 - state income tax rate - federal income tax rate). For example, if the required net income in 1977 is $1.7 billion, the required earnings before taxes would be 1.7/(1 - .261 - .076) which is equal to $2.6 billion. These calculations are shown below.

CALCULATION OF INCOME TAXES
(billions of current dollars)

	1977
Required Net Income	$ 1.72
Average Federal Tax Rate	25.1%
Average State Tax Rate	7.6%
Total Income Tax Rate	33.7%
Required Earnings Before Income Taxes	$ 2.60

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[3] *The source of the effective state tax rate is the economic impact report on the iron and steel industry published by the National Bureau of Economic Research (NBER) for the Department of Commerce.*

[4] *The 26.1 percent figure represents the average effective rate for the past decade as reported in the* Annual Statistical Report *of the American Iron and Steel Institute.*

INTEREST CHARGES

The third expense considered in the construction of the income statement is interest charges for long-term debt. Expenses for long-term debt issued prior to 1972 are determined from the actual charges being paid on this debt as reported in the 1974 Annual Statistical Report of the American Iron and Steel Institute. From these data the interest and charges on embedded long-term debt are calculated to be 6.1 percent of total long-term debt outstanding. The flow of funds logic in PTm(Steel) makes provision to refund part of the embedded debt in each future year until all of the debt is refunded. In this analysis 4.1 percent of the initial embedded debt is refunded in each year. Interest charges on the remaining portion of this embedded debt are calculated for each future year using 6.1 percent as the interest rate.

Interest expenses for post-1972 debt are calculated based on the interest rate forecast for the year of issue. These yearly interest rates were developed by calculations similar to those used for return on equity. First, actual interest rates for Baa rated bonds[5] for the years from 1965 through 1974 were corrected for each year's inflation to yield a "real" or above-inflation return. For example, in 1970 the average Baa interest rate was 9.1 percent, and inflation in that year as measured by the change in the GNP deflator was 5.5 percent. The resulting "real" Baa interest rate for 1970 was 3.6 percent. Similar calculations were performed for all of the years from 1965 to 1974, and the average real interest rate for the period was found to be approximately 3 percent. This number measures on average the amount over and above inflation that the borrower must pay.

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[5] *Source: Moody's Industrials Manual. Baa ratings were used as a conservative estimate of steel industry ratings. Actual industry ratings have historically been somewhat higher.*

The annual interest rates for use in the period from 1975 to 1985 were computed from the real interest rate of 3 percent and forecasts of inflation. This was done by adding to the real interest rate each year's forecast percentage change in the GNP deflator. For instance, in 1977 the GNP deflator is assumed to grow by 6.5 percent. Thus the required rate of interest on long-term debt issued in 1977 is 9.5 percent. The interest rates resulting from similar calculations are displayed in Exhibit 37. The actual interest rates paid by the industry are used in PTm(Steel) for 1972, 1973, and 1974. Computation of requirements for long-term debt issues is done in the flow of funds logic and will be discussed below.

Using the interest rates as calculated above, the total interest expense for 1977 would be calculated as follows. Total long-term debt outstanding at the end of 1977 is $6.1 billion. This total is made up of the remaining embedded debt and the new debt issued in each year. The table below shows the calculation of total 1977 interest expense. The remaining embedded debt is 75.4 percent of the original embedded debt because 4.1 percent of the embedded total has been refunded in each of the six years from 1972 to 1977.

CALCULATION OF INTEREST EXPENSE
(billions of current dollars)

1977

	Remaining Embedded Debt	Interest Rate	Total Charge
	$3.09	6.1%	$.19
	New Issues of Debt	Interest Rate	Total Charge
1972	$ .31	7.4%	$.02
1973	.06	7.8%	.01
1974	.25	9.5%	.02
1975	1.43	12.5%	.18
1976	0	10.1%	-
1977	.98	9.5%	.09
Total Interest Charge in 1977			$.51

DEPRECIATION EXPENSE

In general, PTm(Steel) calculated depreciation expense by dividing the gross value of production and pollution control facilities by the appropriate lifetime for depreciation purposes. Thus depreciation calculations are based on the straight-line method. The lifetimes used are 18 years for production equipment and 14.5 years for pollution control equipment.[6] PTm(Steel) accumulates total depreciation charges over time for given investments.

The gross values for production equipment include the initial cost of the facility plus reinvestments in modernization and maintenance of the facility. The pollution control equipment gross value includes the initial cost only. All of those values and the timing of installation are specified by PTm(Steel) for all investments and reinvestments after 1972.

Equipment and facilities in place in 1972 present more of a problem because data concerning the exact value and timing of installation is not available for use in this analysis. To solve this problem, TBS used the capacity profile data provided by ADL and assumed a uniform stream of investments over the 18 years from 1954 to 1972. A technical description of these depreciation calculations is presented in Appendix B.

PROPERTY TAXES

Property taxes are calculated by PTm(Steel) based on the total book value of the industry's fixed assets in each year and the property tax rate. The property tax rate used for all years of the analysis is 2.38 percent.[7] For example, the 1977 total book value is $15.7 billion and thus the computed total property tax would equal $.4 billion. These calculations are displayed in the following table:

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[6] *AISI Advisory Committee and "Steel Industry Economics and Federal Income Tax Policy," AISI, June 1975, page 38.*

[7] *The source of the effective state tax rate is the economic impact report on the iron and steel industry published by the National Bureau of Economic Research (NBER) for the Department of Commerce.*

CALCULATION OF PROPERTY TAXES
(billions of current dollars)

	1977
Total Book Value of Fixed Assets	$15.70
Property Tax Rate	2.38%
Total Property Taxes	$ .37

OPERATIONS AND MAINTENANCE EXPENSES

Operations and maintenance expenses for both production and pollution control equipment are calculated in the cost modules of PTm(Steel). These calculations have been described in Section 1 of this volume. For the purposes of this discussion, operations and maintenance costs are treated as an input to the finance module of PTm(Steel).

SALES TAXES

Sales taxes are the final line item to be calculated in the construction of the income statement. By summing all of the previous expense items plus the required net income, PTm(Steel) arrives at the required revenues after sales tax. Division of this sum by the factor (1.0 - sales tax rate) yields the total required revenues. PTm(Steel) uses a sales tax rate of 3.97 percent in all years of the analysis.[8] Thus if the required revenue before sales taxes is $34.8 billion the total required revenue is $36.2 billion and the sales taxes equal $1.4 billion.

REQUIRED REVENUES

Calculation of required revenues, which is performed as described above, completes the construction of the income

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[8] *Ibid.*

statement. Exhibit 34 summarizes the examples discussed in the text and displays the complete income statement produced by PTm(Steel). The average price of steel products can be derived by dividing the total required revenues by total shipments in any year.

CALCULATION OF SALES TAX AND REQUIRED REVENUES
(billions of current dollars)

	1977
Earnings Before Interest and Taxes	$ 3.11
Depreciation	1.65
Operating and Maintenance	29.67
Property Tax	.37
Required Revenues Before Sales Tax	$34.80
Sales Tax Rate	3.97%
Total Required Revenues	$36.24
Sales Tax	$ 1.44

A similar process is used to calculate income statements for a single product or process. In these calculations, process-specific charges are used for operating and maintenance expenses, depreciation, property taxes and sales taxes. Product-specific charges are arrived at by allocating process costs to products using the proportion of each process's production which goes to each product and the total flows through processes. Other expenses, such as required net income, income taxes and interest charges are allocated first to processes based on each process's percent of the total book value and then to products if necessary by using the process-product proportions. These are displayed in Exhibit 4 of this volume.

THE FLOW OF FUNDS

The flow of funds logic in PTm(Steel) sums the uses of funds in each year of the analysis and compares this total requirement with the amount of funds generated internally. If more funds are needed than are available from internal sources, long-term debt and equity are issued in amounts that maintain the specified debt-to-equity ratio for the industry. If there is an excess of internal funds, this excess is invested in short-term instruments with an interest rate 1 percent below the long-term interest rate for that year. The flow of funds logic is displayed in Exhibit 33. The actual calculation of the flow of funds at the same time as the calculation of the income statement requires the solution of a set of simultaneous equations. An example of a flow of funds statement as produced by PTm(Steel) is shown in Exhibit 35.

USES OF FUNDS

There are three uses of funds in the steel industry as modeled by PTm(Steel). The calculation of each of these is explained and displayed in the table below. The first use of funds is expenditures for plant put in service plus for changes in construction work in progress for production and pollution control equipment. These expenditures are calculated by the capacity additions and pollution control cost modules and are input to the finance module. As explained in Section 2, capital expenditures for new capacity and pollution control equipment are spread over a period of years to more closely resemble the actual pattern of cash expenditures. In addition, capital expenditures for reworks and modernization of facilities are included in the capital expenditure requirements. The reinvestments are incurred in each year and are not spread over a period of time.

The second use of funds is changes in working capital. Working capital is defined in PTm(Steel) as the industry's current assets minus current liabilities, where the current liabilities do not include long-term debt maturing within the year.

The total amount of working capital required in each year is calculated by the model as a percentage of the previous year's revenues. The percentage used, which is held constant for all years of the analysis, is the average of the actual percentages for 1970 to 1974, based on figures in the AISI Annual Statistical Report. Those ratios ranged only 1.3 percent from 19.8 to 21.1 percent. The average was 20 percent.

PTm(Steel) uses the 20 percent of the previous year's revenues as the current year's required working capital. This amount is then subtracted from the previous year's working capital to yield the change in working capital. An increase in working capital is a use of funds while a decrease is a source of funds due to the resulting partial liquidation of working capital. As an example of these calculations, if the 1976 revenues are equal to $30.1 billion, then the working capital in 1977 would equal $6.0 billion. Since working capital in 1976 is $5.0 billion, the required change in working capital would equal $1.0 billion.

The third use of funds calculated by PTm(Steel) is refundings of long-term debt. Long-term debt outstanding at the beginning of the analysis is input to the model as an initial condition and a percentage of this debt is refunded in each year. The specific percentage used, 4.1 percent, is the average of actual refundings for the past decade as reported by the American Iron and Steel Institute. Because the embedded long-term debt equaled $4.1 billion, PTm(Steel) requires funds to refund $.2 billion worth of this debt in each year of the analysis.

CALCULATION OF USES OF FUNDS
(billions of current dollars)

		1976	1977
A.	Change in Working Capital		
	Working Capital	$ 5.00	$6.03
	Revenues	$30.14	-
	Working Capital as Percent of Previous Years Revenues	20%	20%
	Change in Working Capital		$1.02
B.	Refunding of Long-Term Debt		
	Initial Long-Term Debt		$4.10
	Percentage Refunded in Each Year		4.1%
	Total Refundings		$ .17
C.	Capital Expenditures and Change in CWIP (from Cost Modules)		3.26
D.	Change in Investments		$(.72)
E.	Total Uses		3.74

SOURCES OF FUNDS

Sources of funds for the steel industry as modeled by PTm(Steel) can be classified as internal or external. Internal sources, which include depreciation and retained earnings, are calculated first and compared to the total funds required. If the requirements are greater than the internal sources, long-term debt and equity are issued to meet the deficit. If total internal sources are greater than the fund requirements in a given year, the excess funds are invested in short-term notes. These excess funds then become available as a source of funds in the next year, and the interest earned on them during the year is counted as extra revenue in the calculation of the income statement.

The retained earnings are calculated from the required net income in each year using a dividend payout ratio[9] which is input to the model. For this analysis the dividend payout ratio was calculated from individual company data, as reported in Annual Reports and S.E.C. Form 10K for the past decade. Companies

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[9] *Defined as dividends/net income*

representing 76.5 percent of total raw steel production were included in these calculations. The resulting average dividend payout ratio was calculated as 55.6 percent. Retained earnings in any given year equal the net income minus the dividends, which in turn equal .556 times the net income. Thus retained earnings equal (1.0 - .556) or .444 times the net income. For 1977 retained earnings would equal $.8 billion dollars since required net income was $1.7 billion.

Depreciation charges are calculated as described above and in Appendix B. These charges are then used in both the income statement logic and the flow of funds logic. Depreciation charges are added to retained earnings to yield total internal sources. The box below displays the calculations required to compute the sources of funds.

CALCULATION OF SOURCES OF FUNDS
(billions of current dollars)

	1977
Required Net Income	$1.72
Dividend Payout Percentage	55.6%
Retained Earnings	$ .76
Total Depreciation	1.65
Total Internal Sources	$2.41
Total Funds Requirements	3.74
External Funds Required	1.33

Issues of long-term debt and equity make up the external sources of funds in each year when they are required. Total requirements for external sources are computed by subtracting the available internal sources of funds from the total funds required. The deficit is made up by issues of debt and equity. All of the stockholders' equity within PTm(Steel) is assumed to be common equity, because of the relatively small and decreasing amount of preferred stock in the industry's capital structure in the past 15 years. The relative amounts of debt and equity issued are calculated from a capitalization ratio input to PTm(Steel). This ratio expresses the amount of equity as a percent of total capitalization (long-term debt plus equity). The ratio used in this analysis was calculated from data in the AISI Annual Statistical Reports for the period 1965-1974, and equals 74.2 percent. The actual capitalization ratios were used for 1972, 1973, and 1974.

As an example of the external financing calculations, the 1977 total required uses of funds are $3.7 billion and 1977 total internal sources equal $2.4 billion. Thus, $1.3 billion of funds must be generated through external financing. The amounts of long-term debt and common equity issued are subject to two constraints as shown in the following table. First, the sum of the issues of debt and of common equity must equal the required external financing of $1.3 billion. Second, debt and equity must be issued in proportions that will restore the required capitalization ratio of .742. Thus, calculation of the amounts of debt and equity issued requires the solution of two equations with two unknowns. The results are shown in the table below. Total 1977 additions to common equity are $.4 billion and to long-term debt are $1.0 billion.

CALCULATION OF EXTERNAL FINANCING
(billions of current dollars)

EQ = Common Equity Added
LTD - Long Term Debt Added

A. 1977

(1) $EQ + LTD = \$1.33$ Total Funds Requirement

(2) $\frac{17.53 + EQ}{22.67 + EQ + LTD} = .74$ Capital Structure Requirement

17.53 = 1976 Equity + 1977 Retained Earnings
22.67 = Total 1977 Capitalization Before Financing

Now substitute Equation (1) in denominator of Equation (2):

$$\frac{17.53 + EQ}{22.67 + 1.33} = .74$$

And from Equation (1):

$$LTD = 1.33 - .35 = .98$$

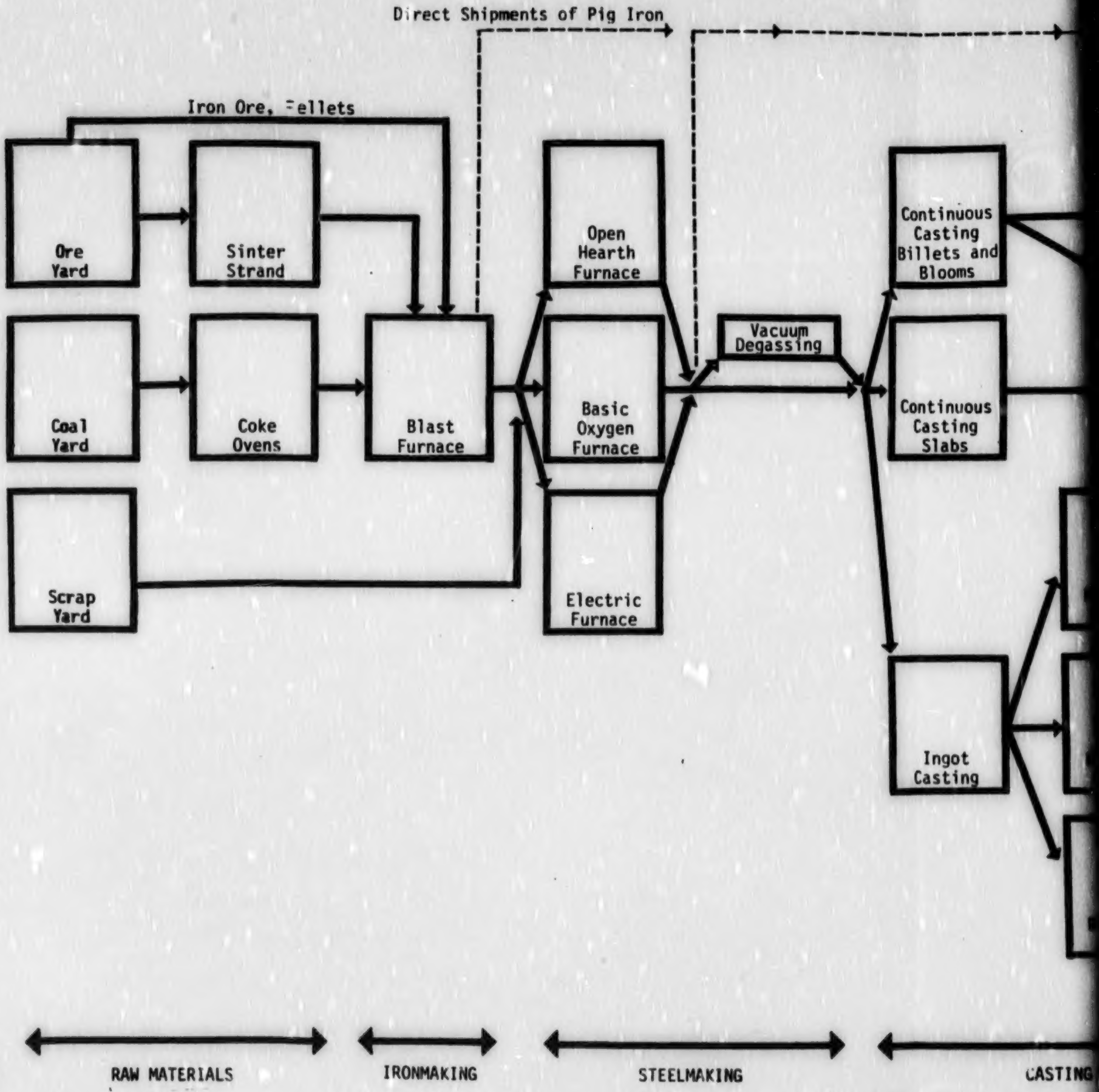
BALANCE SHEET

The operation of the financial analysis module of PTm(Steel) has been described as taking place in two major segments. The first of these calculates an industry income statement for the current year of the analysis, and the second calculates the required issues of long-term debt and common equity through the development of a flow of funds statement. Although these steps have been described separately, they actually occur together in the model through the use of simultaneous equations. The financial module must maintain a complete set of asset and liability accounts in order to perform the calculations described above. Thus, construction of an industry balance sheet for each year of the analysis is a by-product of the modules logic. An example of the balance sheet produced by PTm(Steel) is shown in Exhibit 38.

The design of the finance module is keyed to making the best use of the data available to TBS. Because these data may change in the future, and because of the need for sensitivity analysis, the module is designed to accept more parameters as input. Relatively little data are actually contained in the computer coding.

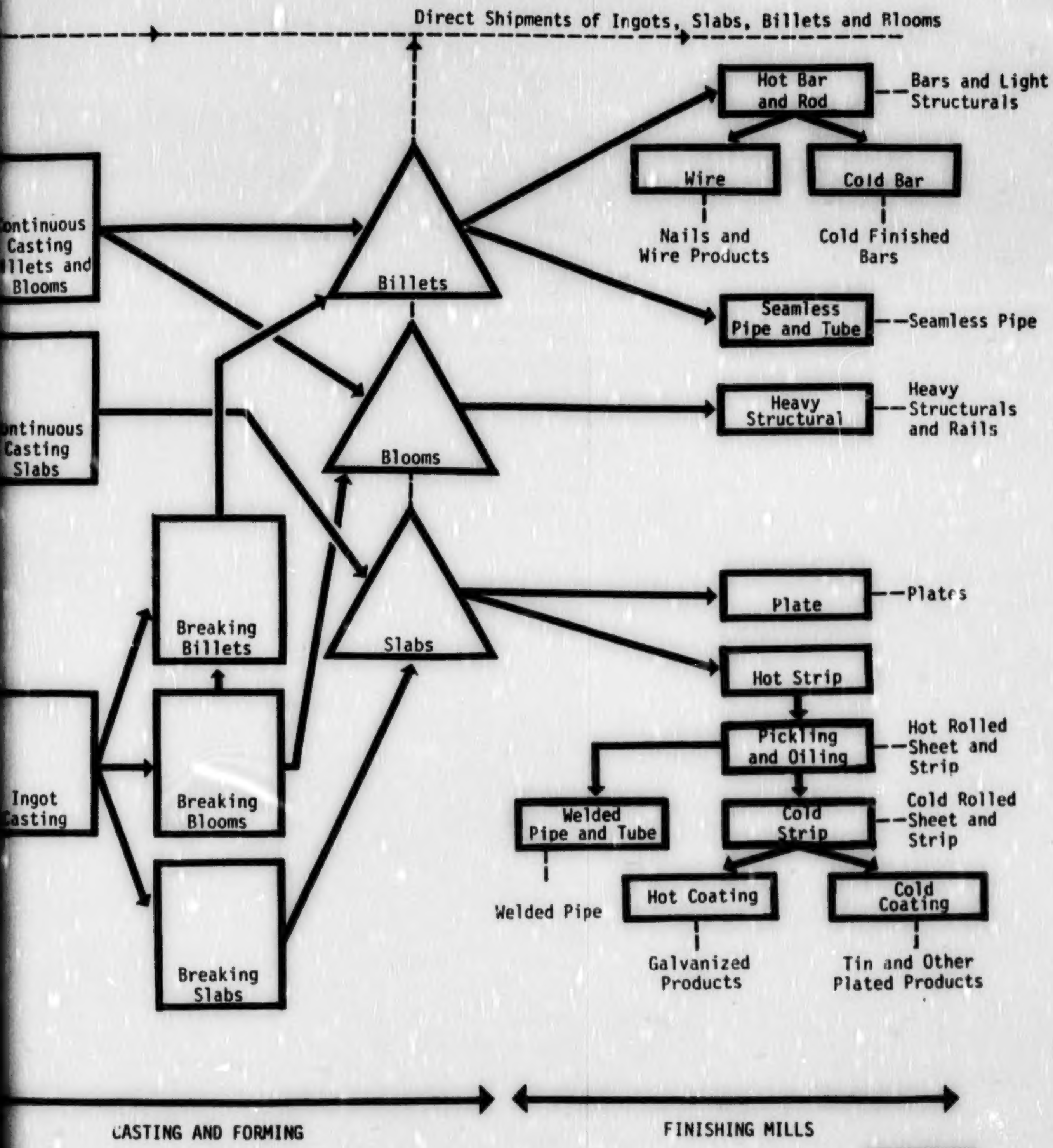
Exhibit 1

STEEL PRODUCTION PR


Direct Shipments of Pig Iron
Iron Ore, Pellets
Ore Yard
Sinter Strand
Coal Yard
Coke Ovens
Blast Furnace
Scrap Yard
Open Hearth Furnace
Basic Oxygen Furnace
Electric Furnace
Vacuum Degassing
Continuous Casting Billets and Blooms
Continuous Casting Slabs
Ingot Casting
RAW MATERIALS
IRONMAKING
STEELMAKING
CASTING

bit 1

ON PROCESSES


Direct Shipments of Ingots, Slabs, Billets and Blooms
ontinuous Casting illets and Blooms
ontinuous Casting Slabs
Ingot Casting
Breaking Billets
Breaking Blooms
Breaking Slabs
Billets
Blooms
Slabs
Hot Bar and Rod
Bars and Light Structurals
Wire
Cold Bar
Nails and Wire Products
Cold Finished Bars
Seamless Pipe and Tube
Seamless Pipe
Heavy Structural
Heavy Structurals and Rails
Plate
Plates
Hot Strip
Pickling and Oiling
Hot Rolled Sheet and Strip
Welded Pipe and Tube
Welded Pipe
Cold Strip
Cold Rolled Sheet and Strip
Hot Coating
Cold Coating
Galvanized Products
Tin and Other Plated Products
CASTING AND FORMING
FINISHING MILLS

TBS

Exhibit 2

COMPARISON OF PRODUCT CATEGORIES

TBS PRODUCT CATEGORIES	AISI PRODUCT CATEGORIES
Direct Shipments of Ingots, Slabs, Billets and Blooms	Ingots and Steel Castings; Blooms, Slabs, Billets, Sheet Bars; Tube Rounds
Heavy Structurals and Rails	Heavy Structural Shapes; Steel Piling; Rails
Nails and Wire Products	Nails and Wires
Bars, Light Structurals, including Bars and Wire Rods	Wire Rods; Bars--Hot Rolled, Light Shaped, and Reinforcing; Tool Steel
Cold Finished Bars	Bars--Cold Finished
Seamless Pipe	Pipes and Tubing--Oil Country Goods and Pressure
Welded Pipe	Pipes and Tubing--Standard, Line, Mechanical, Structural, and Stainless
Hot Rolled Sheet and Strip	Sheets and Strip--Hot Rolled; Skelp
Galvanized Products	Sheets & Strip--Galvanized Hot Dipped and Galvanized Electrolytic
Tin Plating and other Plated Products	Tin Plate--Electrolytic and Hot Dipped; Tin Free Steel; Tin Mill Products--all other; Sheets and Strip--all other Metallic Coated
Cold Rolled Sheet and Strip	Black Plate; Sheets--Cold Rolled; Sheets and Strip--Electrical; Strip--Cold Rolled
Plate	Plates

Exhibit 3

YIELDS BY PROCESS

Process	Tons Out Per Ton In
Raw Materials Preparation	
Ore Yard	1.000
Coal Yard	1.000
Scrap Yard	0.980
Sinter Strand	1.000
Coke Ovens	0.699
Ironmaking	
Blast Furnace	n/a
Steelmaking	
Open Hearth Furnace	n/a
Basic Oxygen Furnace	n/a
Electric Furnace	n/a
Vacuum Degassing	n/a
Casting and Forming	
Continuous Casting	
Billets and Blooms	0.952
Slabs	0.943
Conventional Casting	
Ingot Casting	0.980
Breaking--Blooms	0.885
Breaking--Billets	0.862
Breaking--Slabs	0.833
Finishing Mills	
Heavy Structural	0.833
Hot Rolled Bar and Rod	0.901
Wire Product	0.952
Cold Finished Bar	0.901*
Seamless Pipe and Tube	0.833
Hot Rolled Strip	0.952
Pickling and Oiling	0.943
Welded Pipe and Tube	0.901
Cold Rolled Strip	0.877
Hot Coating--Galvanizing and Terne	0.962
Cold Coating--Tin and Chrome	0.962
Plate	0.794

*Assumed equal to hot rolled bar

n/a = not applicable

Source: Arthur D. Little Industry Survey

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Exhibit 4A

PRODUCTION REQUIREMENTS FOR EACH PRODUCT FROM EACH PROCESS

1972

(tons of production per ton shipped)

Process Names / Product Names	Direct Shipments of Ingots, Slabs, Billets and Blooms	Heavy Structurals and Rails	Wire Products	Bars, Light Structurals	Cold Finished Bars	Seamless Pipe	Welded Pipe	Hot Rolled Sheet and Strip	Galvanized Products	Tin Plated Products	Cold Rolled Sheet and Strip	Plate
Ore Yard	1.14	1.35	1.43	1.36	1.36	1.47	1.47	1.28	1.57	1.57	1.51	1.50
Coal Yard	.59	.70	.74	.70	.70	.76	.76	.66	.81	.81	.78	.77
Scrap Yard	.57	.67	.71	.68	.68	.74	.73	.64	.78	.78	.75	.75
Sinter Strand	.25	.30	.32	.30	.30	.33	.33	.28	.35	.35	.33	.33
Coke Ovens	.41	.49	.52	.49	.49	.53	.53	.46	.57	.57	.55	.54
Blast Furnace	.72	.85	.91	.86	.86	.93	.93	.81	1.00	1.00	.96	.95
Open Hearth Furnace	.30	.36	.38	.36	.36	.39	.39	.34	.42	.42	.40	.40
Basic Oxygen Furnace	.65	.77	.82	.78	.78	.84	.84	.73	.90	.90	.86	.86
Electric Furnace	.21	.24	.26	.25	.25	.27	.27	.23	.23	.23	.27	.27
Ingot Casting	1.07	1.26	1.29	1.23	1.23	1.33	1.38	1.20	1.47	1.47	1.42	1.41
Contin. Cast--Billets & Blooms	.05	.08	.13	.13	.13	.14	0	0	0	0	0	0
Contin. Cast--Slabs	.02	0	0	0	0	0	.09	.08	.09	.09	.09	.09
Breaking--Blooms	.38	1.12	.67	.63	.63	.69	0	0	0	0	0	0
Breaking--Billets	.23	0	1.08	1.03	1.03	1.12	0	0	0	0	0	0
Breaking--Slabs	.23	0	0	0	0	0	1.15	1.00	1.23	1.23	1.18	1.17
Heavy Structural	0	1.00	0	0	0	0	0	0	0	0	0	0
Hot Rolled Bar and Rod	0	0	1.05	1.00	1.00	0	0	0	0	0	0	0
Wire Product	0	0	1.00	0	0	0	0	0	0	0	0	0
Cold Finished Bar	0	0	0	0	1.00	0	0	0	0	0	0	0
Seamless Pipe and Tube	0	0	0	0	0	1.00	0	0	0	0	0	0
Hot Rolled Strip	0	0	0	0	0	0	1.13	1.03	1.26	1.26	1.21	0
Pickling and Oiling	0	0	0	0	0	0	1.11	.42	1.19	1.19	1.14	0
Welded Pipe and Tube	0	0	0	0	0	0	1.00	0	0	0	0	0
Cold Rolled Strip	0	0	0	0	0	0	0	0	1.04	1.04	1.00	0
Hot Coating--Galvanizing & Terne	0	0	0	0	0	0	0	0	1.03	0	0	0
Cold Coating--Tin and Chrome	0	0	0	0	0	0	0	0	0	1.00	0	0
Plate	0	0	0	0	0	0	0	0	0	0	0	1.00
Vacuum Degassing	.30	.35	.37	.36	.36	.38	.38	.33	.41	.41	.39	.39

Source: PTm(steel)

Exhibit 4B

PRODUCTION REQUIREMENTS FOR EACH PRODUCT FROM EACH PROCESS

1975

(tons of production per ton shipped)

Product Names Process Names	Direct Shipments of Ingots, Slabs, Billets and Blooms	Heavy Structurals and Rails	Wire Products	Bars, Light Structurals	Cold Finished Bars	Seamless Pipe	Welded Pipe	Hot Rolled Sheet and Strip	Galvanized Products	Tin Plated Products	Cold Rolled Sheet and Strip	Plate
Ore Yard	1.12	1.33	1.41	1.34	1.34	1.45	1.45	1.27	1.55	1.55	1.49	1.48
Coal Yard	.58	.69	.73	.69	.69	.75	.75	.65	.80	.80	.77	.76
Scrap Yard	.57	.68	.72	.68	.68	.74	.74	.64	.79	.79	.76	.75
Sinter Strand	.25	.30	.31	.30	.30	.32	.32	.28	.34	.34	.33	.33
Coke Ovens	.41	.48	.51	.48	.48	.52	.52	.46	.56	.56	.54	.53
Blast Furnace	.71	.84	.89	.85	.85	.92	.92	.80	.98	.98	.94	.94
Open Hearth Furnace	.27	.32	.34	.32	.32	.35	.35	.30	.37	.37	.36	.35
Basic Oxygen Furnace	.66	.79	.83	.79	.79	.86	.86	.75	.92	.92	.88	.88
Electric Furnace	.22	.26	.28	.27	.27	.29	.29	.25	.31	.31	.30	.29
Ingot Casting	1.04	1.23	1.24	1.13	1.18	1.28	1.34	1.17	1.43	1.43	1.38	1.37
Contin. Cast--Billets & Blooms	.06	.11	.18	.17	.17	.18	0	0	0	0	0	0
Contin. Cast--Slabs	.02	0	0	0	0	0	.12	.10	.13	.13	.12	.12
Breaking--Blooms	.36	1.09	.63	.60	.60	.65	0	0	0	0	0	0
Breaking--Billets	.23	0	1.05	1.00	1.00	1.09	0	0	0	0	0	0
Breaking--Slabs	.23	0	0	0	0	0	1.12	.97	1.19	1.19	1.15	1.14
Heavy Structural	0	1.00	0	0	0	0	0	0	0	0	0	0
Hot Rolled Bar and Rod	0	0	1.05	1.00	1.00	0	0	0	0	0	0	0
Wire Product	0	0	1.00	0	0	0	0	0	0	0	0	0
Cold Finished Bar	0	0	0	0	1.00	0	0	0	0	0	0	0
Seamless Pipe and Tube	0	0	0	0	0	1.00	0	0	0	0	0	0
Hot Rolled Strip	0	0	0	0	0	0	1.19	1.03	1.26	1.26	1.21	0
Pickling and Oiling	0	0	0	0	0	0	1.11	.42	1.19	1.19	1.14	0
Welded Pipe and Tube	0	0	0	0	0	0	1.00	0	0	0	0	0
Cold Rolled Strip	0	0	0	0	0	0	0	0	1.04	1.04	1.00	0
Hot Coating--Galvanizing & Terne	0	0	0	0	0	0	0	0	1.00	0	0	0
Cold Coating--Tin and Chrome	0	0	0	0	0	0	0	0	0	1.00	0	0
Plate	0	0	0	0	0	0	0	0	0	0	0	1.00
Vacuum Degassing	.31	.37	.39	.37	.37	.40	.40	.35	.43	.43	.41	.41

Source: PTm (steel)

Exhibit 4C

PRODUCTION REQUIREMENTS
FOR EACH PRODUCT FROM EACH PROCESS

1977

(tons of production per ton shipped)

Product Names / Process Names	Direct Shipments of Ingots, Slabs, Billets and Blooms	Heavy Structurals and Rails	Wire Products	Bars, Light Structurals	Cold Finished Bars	Seamless Pipe	Welded Pipe	Hot Rolled Sheet and Strip	Galvanized Products	Tin Plated Products	Cold Rolled Sheet and Strip	Plate
Ore Yard	1.12	1.33	1.40	1.33	1.33	1.44	1.45	1.26	1.54	1.54	1.48	1.47
Coal Yard	.58	.69	.72	.69	.69	.74	.75	.65	.80	.80	.77	.76
Scrap Yard	.57	.68	.71	.68	.68	.73	.73	.64	.78	.78	.75	.75
Sinter Strand	.25	.29	.31	.30	.30	.32	.32	.28	.34	.34	.33	.33
Coke Ovens	.40	.48	.51	.48	.48	.52	.52	.45	.56	.56	.54	.53
Blast Furnace	.71	.84	.89	.84	.84	.91	.92	.80	.98	.98	.94	.93
Open Hearth Furnace	.23	.27	.29	.27	.27	.30	.30	.26	.32	.32	.31	.30
Basic Oxygen Furnace	.69	.82	.86	.82	.82	.89	.89	.78	.95	.95	.91	.91
Electric Furnace	.23	.27	.29	.28	.28	.30	.30	.26	.32	.32	.31	.30
Ingot Casting	1.01	1.19	1.13	1.12	1.12	1.21	1.29	1.12	1.38	1.38	1.33	1.32
Contin. Cast--Billets & Blooms	.08	.15	.23	.22	.22	.24	0	0	0	0	0	0
Contin. Cast--Slabs	.03	0	0	0	0	0	.16	.14	.17	.17	.16	.16
Breaking--Blooms	.35	1.05	.59	.56	.56	.61	0	0	0	0	0	0
Breaking--Billets	.22	0	1.02	.97	.97	1.05	0	0	0	0	0	0
Breaking--Slabs	.22	0	0	0	0	0	1.08	.94	1.15	1.15	1.10	1.10
Heavy Structural	0	1.00	0	0	0	0	0	0	0	0	0	0
Hot Rolled Bar and Rod	0	0	1.05	1.00	1.00	0	0	0	0	0	0	0
Wire Product	0	0	1.00	0	0	0	0	0	0	0	0	0
Cold Finished Bar	0	0	0	0	1.00	0	0	0	0	0	0	0
Seamless Pipe and Tube	0	0	0	0	0	1.00	0	0	0	0	0	0
Hot Rolled Strip	0	0	0	0	0	0	1.13	1.03	1.26	1.26	1.21	0
Pickling and Oiling	0	0	0	0	0	0	1.11	.42	1.19	1.19	1.14	0
Welded Pipe and Tube	0	0	0	0	0	0	1.00	0	0	0	0	0
Cold Rolled Strip	0	0	0	0	0	0	0	0	1.04	1.04	1.00	0
Hot Coating--Galvanizing & Terne	0	0	0	0	0	0	0	0	1.00	0	0	0
Cold Coating--Tin and Chrome	0	0	0	0	0	0	0	0	0	1.00	0	0
Plate	0	0	0	0	0	0	0	0	0	0	0	1.00
Vacuum Degassing	.32	.38	.40	.38	.38	.41	.41	.36	.44	.44	.43	.42

Source: PTm(steel)

Exhibit 4D

PRODUCTION REQUIREMENTS
FOR EACH PRODUCT FROM EACH PROCESS

1980

(tons of production per ton shipped)

Product Names / Process Names	Direct Shipments of Ingots, Slabs, Billets and Blooms	Heavy Structurals and Rails	Wire Products	Bars, Light Structurals	Cold Finished Bars	Seamless Pipe	Welded Pipe	Hot Rolled Sheet and Strip	Galvanized Products	Tin Plated Products	Cold Rolled Sheet and Strip	Plate
Ore Yard	1.11	1.32	1.39	1.32	1.32	1.43	1.43	1.25	1.53	1.53	1.47	1.46
Coal Yard	.57	.68	.71	.68	.68	.74	.74	.64	.79	.79	.76	.75
Scrap Yard	.56	.67	.70	.67	.67	.73	.73	.63	.78	.78	.75	.74
Sinter Strand	.25	.29	.31	.29	.29	.32	.32	.28	.34	.34	.33	.32
Coke Ovens	.40	.48	.50	.48	.48	.51	.52	.45	.55	.55	.53	.53
Blast Furnace	.70	.84	.88	.84	.84	.90	.91	.79	.97	.97	.93	.93
Open Hearth Furnace	.18	.21	.22	.21	.21	.23	.23	.20	.24	.24	.23	.23
Basic Oxygen Furnace	.72	.86	.90	.86	.86	.93	.93	.81	1.00	1.00	.96	.95
Electric Furnace	.24	.29	.30	.29	.29	.31	.31	.27	.34	.34	.32	.32
Ingot Casting	.96	1.13	1.08	1.03	1.03	1.11	1.21	1.05	1.29	1.29	1.24	1.23
Contin. Cast--Billets & Blooms	.11	.20	.31	.29	.29	.32	0	0	0	0	0	0
Contin. Cast--Slabs	.05	0	0	0	0	0	.23	.20	.24	.24	.23	.23
Breaking--Blooms	.32	1.00	.53	.50	.50	.55	0	0	0	0	0	0
Breaking--Billets	.21	0	.97	.92	.92	1.00	0	0	0	0	0	0
Breaking--Slabs	.20	0	0	0	0	0	1.01	.88	1.08	1.08	1.04	1.03
Heavy Structural	0	1.00	0	0	0	0	0	0	0	0	0	0
Hot Rolled Bar and Rod	0	0	1.05	1.00	1.00	0	0	0	0	0	0	0
Wire Product	0	0	1.00	0	0	0	0	0	0	0	0	0
Cold Finished Bar	0	0	0	0	1.00	0	0	0	0	0	0	0
Seamless Pipe and Tube	0	0	0	0	0	1.00	0	0	0	0	0	0
Hot Rolled Strip	0	0	0	0	0	0	1.18	1.03	1.25	1.26	1.21	0
Pickling and Oiling	0	0	0	0	0	0	1.11	.42	1.19	1.19	1.14	0
Welded Pipe and Tube	0	0	0	0	0	0	1.00	0	0	0	0	0
Cold Rolled Strip	0	0	0	0	0	0	0	0	1.04	1.04	1.00	0
Hot Coating--Galvanizing & Terne	0	0	0	0	0	0	0	0	1.00	0	0	0
Cold Coating--Tin and Chrome	0	0	0	0	0	0	0	0	0	1.00	0	0
Plate	0	0	0	0	0	0	0	0	0	0	0	1.00
Vacuum Degassing	.34	.40	.42	.40	.40	.43	.44	.38	.46	.46	.45	.44

Source: PTm(steel)

Exhibit 4E

PRODUCTION REQUIREMENTS FOR EACH PRODUCT FROM EACH PROCESS

1983

(tons of production per ton shipped)

Process Names \ Product Names	Direct Shipments of Ingots, Slabs, Billets and Blooms	Heavy Structurals and Rails	Wire Products	Bars, Light Structurals	Cold Finished Bars	Seamless Pipe	Welded Pipe	Hot Rolled Sheet and Strip	Galvanized Products	Tin Plated Products	Cold Rolled Sheet and Strip	Plate
Ore Yard	1.10	1.32	1.36	1.30	1.30	1.41	1.42	1.24	1.52	1.52	1.46	1.45
Coal Yard	.57	.68	.70	.67	.67	.72	.73	.64	.78	.78	.75	.75
Scrap Yard	.56	.67	.69	.66	.66	.71	.72	.63	.77	.77	.74	.74
Sinter Strand	.24	.29	.30	.29	.29	.31	.32	.27	.34	.34	.32	.32
Coke Ovens	.40	.47	.49	.47	.47	.51	.51	.45	.55	.55	.53	.52
Blast Furnace	.70	.83	.86	.82	.82	.89	.90	.78	.96	.96	.92	.92
Open Hearth Furnace	.14	.16	.17	.16	.16	.17	.18	.15	.19	.19	.18	.13
Basic Oxygen Furnace	.75	.89	.92	.38	.88	.95	.96	.84	1.03	1.03	.99	.98
Electric Furnace	.25	.30	.31	.30	.30	.32	.32	.28	.35	.35	.33	.33
Ingot Casting	.89	1.02	.94	.89	.89	.96	1.12	.98	1.20	1.20	1.15	1.14
Contin. Cast--Billets & Blooms	.15	.29	.43	.41	.41	.44	0	0	0	0	0	0
Contin. Cast--Slabs	.06	0	0	0	0	0	.30	.26	.32	.32	.31	.31
Breaking--Blooms	.28	.91	.44	.42	.42	.45	0	0	0	0	0	0
Breaking--Billets	.19	0	.88	.84	.84	.91	0	0	0	0	0	0
Breaking--Slabs	.19	0	0	0	0	0	.93	.81	1.00	1.00	.96	.95
Heavy Structural	0	1.00	0	0	0	0	0	0	0	0	0	0
Hot Rolled Bar and Rod	0	0	1.05	1.00	1.00	0	0	0	0	0	0	0
Wire Product	0	0	1.00	0	0	0	0	0	0	0	0	0
Cold Finished Bar	0	0	0	0	1.00	0	0	0	0	0	0	0
Seamless Pipe and Tube	0	0	0	0	0	1.00	0	0	0	0	0	0
Hot Rolled Strip	0	0	0	0	0	0	1.13	1.03	1.26	1.26	1.21	0
Pickling and Oiling	0	0	0	0	0	0	1.11	.42	1.19	1.19	1.14	0
Welded Pipe and Tube	0	0	0	0	0	0	1.00	0	0	0	0	0
Cold Rolled Strip	0	0	0	0	0	0	0	0	1.04	1.04	1.00	0
Hot Coating--Galvanizing & Terne	0	0	0	0	0	0	0	0	1.00	0	0	0
Cold Coating--Tin and Chrome	0	0	0	0	0	0	0	0	0	1.00	0	0
Plate	0	0	0	0	0	0	0	0	0	0	0	1.00
Vacuum Degassing	.35	.42	.43	.41	.41	.44	.45	.39	.43	.43	.46	.46

Source: PTm(steel)

Exhibit 5

PLANNING UTILIZATIONS

Process	Percent of Capacity
Raw Materials Preparation	
Ore Yard	90.0
Coal Yard	90.0
Scrap Yard	90.0
Sinter Strand	90.0
Coke Ovens	90.0
Ironmaking	
Blast Furnace	90.0
Steelmaking	
Open Hearth Furnace	90.0
Basic Oxygen Furnace	90.0
Electric Furnace	90.0
Vacuum Degassing	n.a.
Casting and Forming	
Continuous Casting	
Billets and Blooms	90.0
Slabs	90.0
Conventional Casting	
Ingot Casting	90.0
Breaking--Blooms	85.0
Breaking--Billets	85.0
Breaking--Slabs	85.0
Finishing Mills	
Heavy Structural	75.0
Hot Rolled Bar and Rod	75.0
Wire Product	75.0
Cold Finished Bar	75.0
Seamless Pipe and Tube	75.0
Hot Rolled Strip	85.0
Pickling and Oiling	85.0
Welded Pipe and Tube	75.0
Cold Rolled Strip	75.0
Hot Coating--Galvanizing and Terne	75.0
Cold Coating--Tin and Chrome	75.0
Plate	75.0

n.a. = not available

Source: AISI Advisory Committee

Exhibit 6

CAPITAL COST OF ROUNDOUT CAPACITY ADDITIONS
(1975 Dollars)

Process	$/Ton
Raw Materials Preparation	
Ore Yard	8.59
Coal Yard	8.59
Scrap Yard	5.47
Sinter Strand	23.54
Coke Ovens	123.00
Ironmaking	
Blast Furnace	46.09
Steelmaking	
Open Hearth Furnace	36.00
Basic Oxygen Furnace	25.00
Electric Furnace	25.00
Vacuum Degassing	n.a.
Casting and Forming	
Continuous Casting	
Billets and Blooms	65.63
Slabs	47.66
Conventional Casting	
Ingot Casting	6.19
Breaking--Blooms	48.75
Breaking--Billets	103.53
Breaking--Slabs	47.64
Finishing Mills	
Heavy Structural	332.03
Hot Rolled Bar and Rod	156.00
Wire Product	422.00
Cold Finished Bar	n.a.
Seamless Pipe and Tube	304.00
Hot Rolled Strip	59.38
Pickling and Oiling	32.03
Welded Pipe and Tube	234.38
Cold Rolled Strip	189.84
Hot Coating--Galvanizing and Terne	271.88
Cold Coating--Tin and Chrome	172.00
Plate	170.31

n.a. = not available

Source: AISI Advisory Committee

Exhibit 7

REINVESTMENT RATE FOR MODERNIZATION BY PROCESS

Process	Percent of Initial Investment Reinvested Each Year
Raw Materials Preparation	
Ore Yard	1.0
Coal Yard	1.0
Scrap Yard	1.0
Sinter Strand	1.0
Coke Ovens	3.0
Ironmaking	
Blast Furnace	1.5
Steelmaking	
Open Hearth Furnace	2.0
Basic Oxygen Furnace	1.0
Electric Furnace	1.0
Vacuum Degassing	n.a.
Casting and Forming	
Continuous Casting	
Billets and Blooms	1.0
Slabs	1.0
Conventional Casting	
Ingot Casting	1.0
Breaking--Blooms	3.5
Breaking--Billets	3.5
Breaking--Slabs	3.5
Finishing Mills	
Heavy Structural	3.0
Hot Rolled Bar and Rod	6.8
Wire Product	5.0
Cold Finished Bar	n/a
Seamless Pipe and Tube	4.0
Hot Rolled Strip	2.0
Pickling and Oiling	1.7
Welded Pipe and Tube	6.0
Cold Rolled Strip	2.5
Hot Coating--Galvanizing and Terne	2.0
Cold Coating--Tin and Chrome	3.0
Plate	1.0

n.a. = not available

Source: Arthur D. Little Industry Survey

Exhibit 8A

RESOURCE REQUIREMENTS FOR STEELMAKING

PHASE I PROCESSES

Phase I Processes	Inputs (tons)							
	Ore	Coal	Scrap	Sinter	Coke	Pellets	Hot Metal*	Raw Steel**
Ore Yard	1.00	-	-	-	-	-	-	-
Coal Yard	-	1.00	-	-	-	-	-	-
Scrap Yard	-	-	1.02	-	-	-	-	-
Sinter Strand	-	-	-	1.00***	-	-	-	-
Coke Oven	-	1.43	-	-	-	-	-	-
Blast Furnace	0.69	-	-	0.35	0.57	0.84	-	-
Open Hearth Furnace	-	-	0.52	-	-	-	0.62	-
Basic Oxygen Furnace	-	-	0.32	-	-	-	0.81	-
Electric Furnace	-	-	1.09	-	-	-	-	-
Ingot Casting	-	-	-	-	-	-	-	1.02
Continuous Casting--Slabs	-	-	-	-	-	-	-	1.06
Continuous Casting--Billets and Blooms	-	-	-	-	-	-	-	1.05

Phase I Processes	Costs											Outputs		
	Labor (manhours/ton)			Overhead and Selling, General and Administrative ($/ton)										
	Small	Medium	Large	Small	Medium	Large	Power (kwh/ton)	Fuel (mmBtu/ton)	Water (mgal/ton)	Other Raw Material ($/ton)	Maintenance and Miscellaneous ($/ton)	Scrap Out (tons)	Energy Credit (mmBtu)	Other Raw Material Credit ($/ton)
Ore Yard	0.10	0.08	0.06	0.55	0.45	0.34	3.50	-	0.01	-	0.56	-	-	-
Coal Yard	0.09	0.07	0.05	0.66	0.48	0.38	4.35	0.03	0.05	-	0.83	-	-	-
Scrap Yard	0.34	0.21	0.20	4.09	2.47	2.33	4.65	-	0.04	-	1.22	-	-	-
Sinter Strand	0.29	-	0.30	2.29	-	2.36	45.39	1.31	0.38	-	1.88	-	-	-
Coke Oven	0.66	0.53	0.43	5.21	4.19	3.44	23.80	-	5.55	-	3.57	-	7.70	1.63
Blast Furnace	0.42	0.35	0.29	2.35	1.99	1.63	24.50	-	10.95	1.46	4.47	0.01	4.43	0.03
Open Hearth Furnace	0.91	-	0.89	19.81	-	19.26	21.74	3.47	6.10	3.80	9.06	0.02	-	0.06
Basic Oxygen Furnace	0.45	-	0.43	8.40	-	8.09	30.44	0.22	2.31	7.85	4.19	0.02	-	0.13
Electric Furnace	2.92	0.81	0.64	77.64	18.47	15.85	483.57	0.24	3.50	3.90	9.79	0.01	-	0.75
Ingot Casting	0.20	0.09	0.03	4.22	1.91	0.52	-	-	-	-	4.06	0.02	-	0.34
Continuous Casting--Slabs	1.38	-	1.08	28.32	-	22.21	9.80	0.79	2.00	-	4.9[illegible]	0.04	-	0.44
Continuous Casting--Billets and Blooms	0.58	-	0.35	3.91	-	2.40	9.80	0.79	2.00	-	2.39	0.03	-	0.51

*Hot metal is defined as the pig iron from the blast furnace.

**Raw steel is defined as the sum of molten steel tonnages from each of the steel furnace types, including open hearth, basic oxygen furnace, and electric furnace.

***Amounts of ore, sinter, and pellets combined to form sinter in a ratio of one ton of raw material to one ton of sinter.

Source: Arthur D. Little Industry Survey

Exhibit 8B

RESOURCE REQUIREMENTS FOR STEELMAKING
PHASE II PROCESSES

Phase II Processes	Inputs (tons)													
	Ingots	Continuous Cast--Blooms	Continuous Cast--Billets	Continuous Cast--Slabs	Primary Brkdn--Blooms	Primary Brkdn--Billets	Primary Brkdn--Slabs	Bar Mill	Hot Strip Mill	Acid	Pickled Steel	Cold Finished Steel	Zinc	Tin
Primary Brkdn--Blooms	1.13	-	-	-	-	-	-	-	-	-	-	-	-	-
Primary Brkdn--Billets	0.44	.05	-	-	-	0.67	-	-	-	-	-	-	-	-
Primary Brkdn--Slabs	1.20	-	-	-	-	-	-	-	-	-	-	-	-	-
Heavy Structurals	-	0.08	-	-	1.12	-	-	-	-	-	-	-	-	-
Hot Rolled Bar & Rod	-	-	0.08	-	-	1.03	-	-	-	-	-	-	-	-
Wire Product	-	-	-	-	-	-	-	1.05	-	-	-	-	-	-
Seamless Pipe & Tube	-	-	0.08	-	-	1.12	-	-	-	-	-	-	-	-
Hot Rolled Strip	-	-	-	0.07	-	-	0.98	-	-	-	-	-	-	-
Pickling & Oiling	-	-	-	-	-	-	-	-	1.06	0.01	-	-	-	-
Welded Pipe & Tube	-	-	-	-	-	-	-	-	-	-	1.11	-	-	-
Cold Finished Bar	-	-	-	-	-	-	-	-	-	-	1.14	-	-	-
Hot Coating--Galvanizing &	-	-	-	-	-	-	-	-	-	-	-	1.04	0.04	-
Cold Coating--Tin	-	-	-	-	-	-	-	-	-	-	-	1.04	-	0.01
Plate Mill		-	-	0.09	-	-	1.17	-	-	-	-	-	-	-

Phase II Processes	Costs											Outputs		
	Labor (manhours/ton)			Overhead and Selling, General and Administrative ($/ton)										
	Small	Medium	Large	Small	Medium	Large	Power (kwh/ton)	Fuel (mmBtu/ton)	Water (mgal/ton)	Other Raw Material ($/ton)	Maintenance and Miscellaneous ($/ton)	Scrap Out (tons)	Energy Credit (mmBtu)	Other Raw Material Credit ($/ton)
Primary Brkdn--Blooms	0.77	-	0.38	8.76	-	4.38	42.00	1.93	1.40	-	3.38	0.11	-	0.59
Primary Brkdn--Billets	2.06	0.83	0.49	23.42	9,40	5.59	42.00	2.33	1.40	-	5.86	0.13	-	3.84
Primary Brkdn--Slabs	0.74	0.31	0.25	8.41	3.49	2.87	42.00	1.50	1.40	-	3.01	0.19	-	3.45
Heavy Structurals	0.64	-	0.37	4.40	-	2.53	168.00	1.90	4.00	-	4.56	0.20	-	0.0
Hot Rolled Bar & Rod	4.61	1.63	0.99	41.91	14.85	9.01	95.20	2.90	9.20	-	5.64	0.09	-	2.79
Wire Product	3.73	-	3.49	44.68	-	41.78	44.80	-	-	-	10.70	-	-	-
Seamless Pipe & Tube	2.60	-	1.14	28.42	-	12.44	224.00	6.75	0.66	-	14.72	0.16	-	0.0
Hot Rolled Strip	1.24	0.60	0.42	24.08	11.68	8.17	116.20	2.80	5.40	-	6.07	0.04	-	0.41
Pickling & Oiling	0.52	0.32	0.30	6.25	3.95	3.69	12.60	-	0.15	-	2.36	0.04	-	1.1[illegible]
Welded Pipe & Tube	4.57	-	1.88	28.48	-	11.71	98.00	6.00	5.00	-	8.31	0.10	-	0.0
Cold Rolled Strip	9.10	1.89	0.95	87.97	18.23	9.16	168.00	1.62	0.26	-	7.03	0.12	-	[illegible].86
Hot Coating--Galvanizing & Terne	1.34	-	0.98	16.64	-	12.16	67.20	1.85	1.20	18.75	10.13	0.02	-	0.34
Cold Coating--Tin	0.98	-	0.63	17.91	-	11.42	148.40	2.20	4.70	37.50	11.03	0.02	-	0.0
Plate Mill	2.89	-	2.75	22.34	-	21.20	134.40	6.60	9.30	-	11.01	0.23	-	2.16

Source: Arthur D. Little Industry Survey

Exhibit 9

PRICES OF RESOURCES

1972-1983

(current dollars)

	1972	1975	1977	1980	1983
Labor (per manhour)	7.10	10.62	13.04	16.31	19.70
Power (per kwh)	0.0140	0.0215	0.0242	0.0278	0.0315
Fuel (per mmBtu)	0.61	2.00	2.27	2.65	3.04
Water (per thousand gal.)	0.10	0.127	0.145	0.169	0.194
Sludge (per ton)	4.00	5.10	5.81	6.77	7.77
Iron Ore (per ton)	14.08	23.09	27.32	33.00	38.86
Coal (per ton)	15.74	36.13	46.35	63.40	84.60
Scrap (per ton)	35.00	86.96	100.72	127.38	158.67

Source:

Power--TBS, An Analysis of Recent Utility Rate Increases, June 1975.
Iron Ore, Coal, and Scrap--AISI Advisory Committee.
All other 1972 prices from American Iron and Steel Institute Study by
Arthur D. Little, Steel and the Environment--A Cost Impact Analysis, May 1975.
Future prices computed using cost escalation factors from Exhibit 10.

Exhibit 10

COST ESCALATION FACTORS FOR 1975 PRICES
1972-1983

	1972	1975	1977	1980	1983
GNP	0.785	1.000	1.140	1.329	1.525
Capital Expenditures					
Productive Capacity	0.765	1.000	1.154	1.361	1.576
Modernization	0.765	1.000	1.154	1.361	1.576
Pollution Control	0.765	1.000	1.154	1.361	1.576
Labor	0.668	1.000	1.227	1.535	1.854
Overhead	0.668	1.000	1.227	1.535	1.854
Other Raw Material	0.800	1.000	1.130	1.306	1.490
Power	0.650	1.000	1.123	1.290	1.463
Fuel	0.306	1.000	1.140	1.329	1.525
Water	0.785	1.000	1.140	1.329	1.525
Supply	0.785	1.000	1.140	1.329	1.525
Sludge	0.785	1.000	1.140	1.329	1.525
Chemical	0.785	1.000	1.140	1.329	1.525
Other	0.785	1.000	1.140	1.329	1.525
Iron Ore	0.610	1.000	1.183	1.429	1.683
Coal	0.436	1.000	1.283	1.755	2.342
Scrap	0.437	1.000	1.158	1.465	1.825

Source:

GNP--Chase Econometric Associates, Inc., GNP inflator provided for EPA

Capital Expenditures, Productive Capacity, Modernization, Pollution Control: Relation of Chemical Engineering construction index to GNP for 1968 to 1974.

Labor, Overhead: Relation of steel industry labor rate from American Iron & Steel Institute Annual Statistical Report to GNP for 1969 to 1974.

Other Raw Materials--Relation of wholesale price index for nonferrous metals to GNP for 1968 to 1974.

Power: TBS forecast of electric utility rates: actual 1972-1974; GNP rates, 1975-1985.

Fuel, Water, Supply, Sludge, Chemica, Other: All at GNP rates

Ore, Coal, Scrap: AISI Advisory Committee

EXHIBIT 11

DOMESTIC STEEL SHIPMENTS 1960-1983

(MILLIONS OF TONS)

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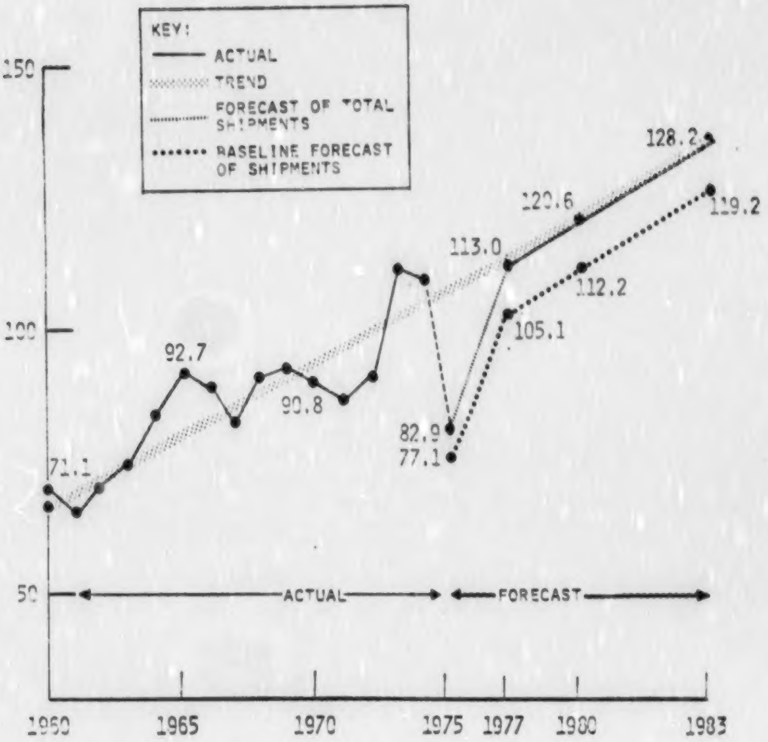

Exhibit 12

PROJECTIONS OF STEEL SHIPMENTS BY PRODUCT
1975-1983
(percentage of total shipments)

Product	Actual		Projections			
	1972	1974	1975	1977	1980	1983
Direct Shipments of Ingots, Blooms, Billets, and Slabs	3.3	3.3	5.3	4.2	4.4	4.5
Heavy Structurals	7.9	8.2	8.3	8.1	8.1	8.0
Hot Rolled Bars & Light Structurals	17.1	16.6	15.2	16.4	16.5	16.6
Wire Products	3.2	2.9	3.7	2.9	2.7	2.6
Cold Finished Bars	1.9	2.1	1.8	2.0	2.0	2.0
Seamless Pipe	2.9	2.4	3.4	3.0	3.0	2.9
Welded Pipe	5.4	6.6	6.0	5.6	5.5	5.4
Hot Rolled Sheet and Strip	17.0	15.7	13.8	16.1	16.5	16.8
Cold Rolled Sheet and Strip	20.4	19.6	20.9	19.8	19.5	19.3
Galvanized Products	5.9	5.6	5.2	5.9	6.0	6.0
Tin and Other Coated Products	6.8	7.1	7.4	6.7	6.6	6.4
Plates	8.2	10.0	9.0	9.3	9.3	9.3
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: PTm(steel)

Exhibit 13

CAPACITY COST
TO PRODUCE 1,000,000 TONS OF PRODUCT WITH 1972 MIX

		Tons		1975 Dollars	
Final Product	Process Number	Production	Capacity	Dollars Per Ton Capacity ($)	Dollar Capacity ($)
Direct Shipment of Unfinished Product		33,000			
Heavy Structural	17	79,000	105,000	322.03	33,813,000
Wire Product	19	32,000	43,000	422.00	18,146,000
Hot Rolled Bar		171,000		-	
Cold Finished Bar	20	19,000	25,000	-	
Seamless Pipe	21	29,000	39,000	304.00	11,856,000
Welded Pipe	24	54,000	72,000	234.38	16,875,000
Hot Rolled Strip		170,000		-	
Hot Coating--Galvanizing and Terne	26	59,000	79,000	271.83	21,475,000
Cold Coating--Tin and Chrome	27	68,000	91,000	185.98	
Cold Rolled Strip		204,000		-	
Plate	28	82,000	109,000	170.31	18,564,000
		1,000,000			
Intermediate Finishing Processes					
Hot Rolled Bar and Rod	18	226,000	301,000	156.00	46,956,000
Cold Rolled Strip	25	336,000	448,000	189.84	84,887,000
Pickling and Oiling	23	613,000	721,000	32.03	23,094,000
Hot Rolled Strip	22	650,000	765,000	59.38	45,426,000
Total Forms		Rolled (Tons) +	Continuous Cast (Tons) =	Total (Tons)	
Billets		266,000	20,000	286,000	
Blooms		250,000	19,000	269,000	
Slabs		731,000	55,000	786,000	
Forming Processes					
Breaking--Blooms	14	250,000	294,000	48.75	14,333,000
Breaking--Billets	15	266,000	313,000	103.53	32,405,000
Breaking--Slabs	16	731,000	860,000	47.64	40,970,000
Subtotal Steel Forming and Finishing					$ 408,804,000
Casting					
Ingot Casting	11	1,468,000	1,631,000	6.19	10,096,000
Continuous Casting--Billets and Blooms	12	39,000	43,000	65.63	2,822,000
Continuous Casting--Slabs	13	55,000	61,000	47.66	2,907,000
Steelmaking					
Open Hearth Furnace	8	418,000	464,000	36.00	16,704,000
Basic Oxygen Furnace	9	894,000	993,000	25.00	24,825,000
Electric Furnace	10	284,000	316,000	29.10	9,196,000
Total Hot Metal		1,596,000			
Ironmaking					
Blast Furnace	7	983,000	1,092,000	46.09	50,330,000
Total Hot Iron		983,000			
Preparation					
Sinter Strand	4	344,000	382,000	23.54	8,992,000
Ore Yard	1	1,553,000	1,726,000	8.59	14,826,000
Coke Ovens	5	560,000	622,000	123.00	76,506,000
Coal Yard	2	801,000	890,000	8.59	7,645,000
Scrap Yard	3	503,000	559,000	5.47	3,058,000
Subtotal Steelmaking					$ 227,907,000
Total					$ 636,711,000

Total Cost Per Ton of Shipments $\frac{\$636,711,000}{1,000,000} = \$636.71$

Total Cost Per Ton of Raw Steel $\frac{\$636,711,000}{1,562,000} = \$407.63$

Source: PTm(steel)

Exhibit 14

TECHNOLOGY CHANGES
1972-1983
(percent)

	1972	1975	1977	1980	1983
	Percent of Molten Steel Produced by Furnace Type				
Steelmaking					
Open Hearth Furnace	26	23	20	16	12
Basic Oxygen Furnace	56	58	60	63	66
Electric Furnace	18	19	20	21	22
	Percent of Molten Steel Vacuum Degassed				
Vacuum Degassing	26	27	28	30	31
	Percent of Billets and Blooms				
Casting and Forming					
Continuous Casting	7	10	12	7	24
Conventional Casting--Breaking	93	90	88	83	76
	Percent of Slabs				
Continuous Casting	7	10	13	18	24
Conventional Casting--Breaking	93	90	87	82	76

Source: Economic & Environmental Analysis, Inc.

Exhibit 15

1972 PROCESS INVENTORY--NUMBER OF UNITS

	Small		Medium		Large	
Process	Pre-1945	Post-1945	Pre-1945	Post-1945	Pre-1945	Post-1945
Raw Materials Preparation						
Ore Yard	14	3	11	5	13	6
Coal Yard	9	5	7	6	8	10
Scrap Yard	10	20	10	16	11	19
Sinter Strand	7	10	0	0	3	14
Coke Ovens	15	29	16	17	10	40
Ironmaking						
Blast Furnace	50	6	51	9	19	38
Steelmaking						
Open Hearth Furnace	0	13	0	0	0	10
Basic Oxygen Furnace	0	16	0	0	0	16
Electric Furnace	5	14	2	20	0	12
Vacuum Degassing	0	0	0	0	0	29
Casting and Forming						
Continuous Casting						
Billets and Blooms	0	8	0	0	0	8
Slabs	0	4	0	0	0	4
Conventional Casting						
Ingot Casting	9	16	5	18	9	20
Breaking--Blooms	8	2	0	0	9	7
Breaking--Billets	5	8	6	6	11	7
Breaking--Slabs	7	7	4	9	4	7
Finishing Mills						
Heavy Structural	0	9	0	0	0	6
Hot Rolled Bar and Rod	10	9	8	11	12	14
Wire Product	0	6	0	0	0	4
Cold Finished Bar	0	0	0	0	0	0
Seamless Pipe and Tube	0	4	0	0	0	3
Hot Rolled Strip	2	11	4	10	4	10
Pickling and Oiling	5	12	3	12	5	11
Welded Pipe and Tube	0	6	0	0	0	6
Cold Rolled Strip	6	15	3	17	4	9
Hot Coating--Galvanizing and Terne	0	9	0	0	0	8
Cold Coating--Tin and Chrome	0	5	0	0	0	5
Plate	0	9	0	0	0	6

Source: Arthur D. Little Industry Survey

Exhibit 16

PLANT SIZE BREAKDOWN BY PROCESS
1972
(capacity in millions of tons)

Process	Small			Medium			Large			Total		
	Pre-1945	Post-1945	Total	Pre-1945	Post-1945	Total	Pre-1945	Post-1945	Total	Pre-1945	Post-1945	Total
Raw Materials												
Ore Yard	19.38	4.43	23.81	34.91	15.78	50.69	87.49	40.52	128.01	141.78	60.73	202.51
Coal Yard	4.78	2.72	7.50	8.87	7.67	16.54	27.74	33.87	61.61	41.39	44.26	85.65
Scrap Yard	1.44	4.19	6.13	7.86	11.68	19.54	17.84	31.76	49.60	27.64	47.63	75.27
Sintering	4.30	6.13	10.43	0	0	0	6.39	30.04	36.43	10.69	36.17	46.86
Coke Oven	3.33	6.59	9.92	5.83	6.18	12.01	8.17	29.42	37.59	17.33	42.19	59.52
Ironmaking												
Blast Furnace	19.93	2.41	22.34	33.54	5.92	39.46	19.12	38.57	57.69	72.59	46.90	119.49
Steelmaking												
Open Hearth	0	15.22	15.22	0	0	0	0	33.88	33.88	0	49.10	49.10
Basic Oxygen Furnace	0	25.73	25.73	0	0	0	0	60.54	60.54	0	86.27	86.27
Electric Furnace	0.48	1.39	1.87	0.90	9.53	10.43	0	13.51	13.51	1.38	24.43	25.81
Vacuum Degassing	0	0	0	0	0	0	0	39.07	39.07	0	39.07	39.07
Forming/Casting												
Ingot Casting	2.60	4.15	6.75	6.40	23.72	29.62	35.17	79.09	114.26	44.17	106.46	150.63
Continuous Casting--Billets	0	1.54	1.54	0	0	0	0	4.20	4.20	0	5.74	5.74
Continuous Casting--Slabs	0	1.71	1.71	0	0	0	0	6.30	6.30	0	8.01	8.01
Finishing												
Primary Breakdown--Blooms	4.51	0	4.51	0	0	0	19.24	7.30	26.54	23.75	7.30	31.05
Primary Breakdown--Billets	1.33	1.13	2.46	3.69	3.69	7.38	15.49	18.93	34.42	20.51	23.75	44.26
Primary Breakdown--Slabs	7.45	2.09	9.54	9.39	21.17	30.56	14.52	25.53	40.05	31.36	48.79	80.15
Heavy Structurals	0	6.69	6.69	0	0	0	0	8.69	8.69	0	15.38	15.38
Bar Mill	1.23	4.26	5.49	2.89	3.91	6.80	11.29	13.19	24.48	15.41	21.36	36.77
Cold Finished Bars	0	0	0	0	0	0	0	3.41	3.41	0	3.41	3.41
Wire Mill	0	0.94	0.94	0	0	0	0	1.90	1.90	0	2.84	2.84
Seamless Pipe	0	1.05	1.05	0	0	0	0	2.64	2.64	0	3.69	3.69
Hot Strip Mill	0.98	5.33	6.31	7.26	18.21	25.47	14.90	39.06	53.96	23.14	62.60	85.74
Pickling	1.63	3.89	5.52	3.37	13.10	16.47	16.03	34.53	50.56	21.03	51.52	72.55
Welded Pipe	0	0.93	0.93	0	0	0	0	3.81	3.81	0	4.74	4.74
Cold Reduction	1.08	2.73	3.81	2.81	16.23	19.04	12.38	12.38	24.76	16.27	31.34	47.61
Galvanizing	*	2.53	2.53	*	0	0	*	5.03	5.03	*	7.56	7.56
Tin Plating	0	2.42	2.42	0	0	0	0	4.40	4.40	0	6.82	6.82
Plate Mill	0	4.67	4.67	0	0	0	0	8.10	8.10	0	12.77	12.77
Ancillary Facilities	0	0	0	0	0	0	0	0	0	0	0	0

*Data given for Region 1 only--inclusive of all pre-1972 data

Source: Arthur D. Little Industry Survey

Exhibit 17

AVERAGE CAPACITY BY PLANT SIZE
1972
(millions of tons)

Process	Small	Medium	Large
Raw Materials Preparation			
Ore Yard	1.40	3.17	6.74
Coal Yard	0.54	1.27	3.42
Scrap Yard	0.20	0.75	1.65
Sinter Strand	0.61	0	2.14
Coke Ovens	0.23	0.36	0.75
Ironmaking			
Blast Furnace	0.40	0.66	1.01
Steelmaking			
Open Hearth Furnace	1.17	0	3.39
Basic Oxygen Furnace	1.61	0	3.78
Electric Furnace	0.10	0.47	1.13
Vacuum Degassing	0	0	1.35
Casting and Forming			
Continuous Casting			
Billets and Blooms	0.20	0	0.53
Slabs	0.43	0	1.58
Conventional Casting			
Ingot Casting	0.27	1.29	3.94
Breaking--Blooms	0.45	0	1.66
Breaking--Billets	0.19	0.62	1.91
Breaking--Slabs	0.68	2.35	3.65
Finishing Mills			
Heavy Structural	0.74	0	1.45
Hot Rolled Bar and Rod	0.29	0.36	0.94
Wire Product	0.16	0	0.48
Cold Finished Bar	0	0	0
Seamless Pipe and Tube	0.26	0	0.88
Hot Rolled Strip	0.49	1.82	3.85
Pickling and Oiling	0.32	1.10	3.16
Welded Pipe and Tube	0.16	0	0.64
Cold Rolled Strip	0.18	0.95	1.91
Hot Coating--Galvanizing and Terne	0.28	0	0.63
Cold Coating--Tin and Chrome	0.48	0	0.88
Plate	0.52	0	1.35

Source: Exhibits 15 & 16

Exhibit 18

ASSOCIATION OF WATER POLLUTION TREATMENT SUBCATEGORIES WITH PRODUCTION PROCESSES

WATER POLLUTION TREATMENT PROCESS	PRODUCTION PROCESSES
By-Product Coking--Alternate I By-Product Coking--Alternate II	Coke Ovens
Sintering	Sinter Strand
Blast Furnace	Blast Furnace
Open Hearth Furnace	Open Hearth Furnace
Basic Oxygen Furnace--Wet Basic Oxygen Furnace--Semi-wet	Basic Oxygen Furnace
Electric Furnace--Wet Electric Furnace--Semi-Wet	Electric Furnace
Vacuum Degassing	Vacuum Degassing
Continuous Casting	Continuous Casting--Billets and Blooms Continuous Casting--Slabs
- - - - - - - - - -	Conventional Casting--Billets, Blooms, and Slabs
Hot Forming--Primary	Primary Breaking--Blooms Primary Breaking--Slabs
Hot Forming--Section	Primary Breaking--Billets Heavy Structural Hot Rolled Bar and Rod Wire Product
Hot Forming--Hot Strip and Sheet	Hot Rolled Strip
Hot Forming--Plate	Plate
Pipe and Tube--Integrated, Seamless, and Other	Seamless Pipe and Tube
Pipe and Tube--Integrated, Welded	Welded Pipe
Pipe and Tube--Isolated, Seamless, or Welded	Seamless Pipe Welded Pipe
Pickling--H_2SO_4 Batch Concentrates and Rinses	Hot Rolled Bar and Rod Wire Production Cold Finished Bar Pipe and Tube--Seamless
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery	Hot Rolled Strip
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I) Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	Hot Rolled Strip
Cold Rolling--Recirculation Cold Rolling--Direct Application Cold Rolling--Combination	Cold Reduction and Finishing
Hot Coating--Galvanizing Hot Coating--Terne	Hot Coating--Galvanizing Hot Coating--Terne
Cold Coating--Tin Cold Coating--Chrome	Cold Coating--Tin and Other Plated Products

Exhibit 19

EFFLUENT GUIDELINES AND TECHNOLOGY LEVEL EQUIVALENCIES

Subcategory	Effluent Guideline Standards*			Other Technologies
	BASE	BPCTCA	BATEA	
By-Product Coke--Alternate I	A	B	C	D
By-Product Coke--Alternate II	A	B	C	
Sintering	A	B+C	D	E
Blast Furnace	A	B	C	
Open Hearth	A	B+C	D	E
Electric Furnace--Wet	A	B+C	D	E
Electric Furnace--Semi-Wet				
Basic Oxygen Furnace--Wet	A	B+C	D	E
Basic Oxygen Furnace--Semi-Wet	A	B	same as BPCTCA	
Vacuum Degassing	A	B	C	D
Continuous Casting		A	B	
Hot Forming--Primary	A	B+C+D+E	G	
Hot Forming--Section	A	B+C+D+E	F+G	
Hot Forming--Hot Strip and Sheet	A	B+C+D+E	F+G	
Hot Forming--Plate	A	B+C+D+E+F+G+H	same as BPCTCA	
Pipe and Tube--Integrated Seamless and Other	A	B+C+D+E	F+G	
Pipe and Tube--Integrated Welded	A	B+C+D+E	G	
Pipe and Tube--Isolated Seamless and Welded	A	B+C+D	E	
Pickling--H_2SO_4 Batch Concentrates and Rinses	A	B	same as BPCTCA	
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization	A_c+A_r	B	C	
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery	A	B	same as BPCTCA	
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I)	A	B	C	
Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	A	B	C	D
Cold Rolling--Recirculation	A	B	same as BPCTCA	
Cold Rolling--Direct Application	A	B	same as BPCTCA	
Cold Rolling--Combination	A	B	same as BPCTCA	
Hot Coatings--Galvanizing	A	B+C	D	
Hot Coatings--Terne	A	B+C	D	
Cold Coatings--Tin	A	$B+C_1+D_1$	E	
Cold Coatings--Chrome	A	$B+C_2+D_2$	E	

Source: EPA, Development Document for Iron and Steel Industry
Point Source Category, Phase I and II; plus TBS calculation

*Letters indicate levels used in the effluent limitations guidelines. Specific delineation of the equipment implied by each level is contained in the development document.

Exhibit 20

EFFLUENT GUIDELINES MODEL PLANT DATA

Subcategory	Model Plant Size (tons/day)	Operating Days/Year	Flows		
			Base	BPT	BAT
				(gals/ton)	
By-Product Coking--Alternate I	2,660	360	175	175	100
By-Product Coking--Alternate II	2,660	360	175	175	100
Sintering	2,980	360	250	50	50
Blast Furnace	3,300	360	1,900	125	125
Open Hearth Furnace	7,400	360	600	50	50
Basic Oxygen Furnace--Wet	7,590	360	600	50	50
Basic Oxygen Furnace--Semi-Wet	4,880	360	430	0	0
Electric Furnace--Wet	1,820	360	240	50	50
Electric Furnace--Semi-Wet	1,640	360	0	0	0
Vacuum Degassing	520	350	560	25	25
Continuous Casting	1,070	360	125	125	125
Hot Forming--Primary	4,000	312	1,334	845	25
No Scarfing	-	-	949	460	25
Hot Forming--Section	1,300	260	6,029	2,626	0
Hot Forming--Hot Strip and Sheet	3,800	312	8,015	4,180	0
Hot Forming--Plate	2,000	260	5,500	150	150
Pipe and Tube--Integrated, Seamless and Other	400	312	4,209	1,002	0
Pipe and Tube--Integrated, Welded	400	312	4,209	1,002	0
Pipe and Tube--Isolated, Seamless or Welded	400	312	4,209	1,002	0
Pickling--H_2SO_4 Batch Concentrates and Rinses	250	260	225	0	0
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization	1,200	312	225	250	50
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery	1,200	312	250	0	0
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I)	3,000	348	220	400	80
Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	3,000	348	220	230	80
Cold Rolling--Combination	1,500	312	400	400	400
Cold Rolling--Recirculation	3,000	348	25	25	25
Cold Rolling--Direct Application	1,000	260	1,000	1,000	1,000
Hot Coatings--Terne with Fume Scrubber	700	260	1,200	1,200	250
Hot Coatings--Terne without Fume Scrubber	700	260	600	600	100
Hot Coatings--Galvanizing with Fume Scrubber	700	260	1,200	1,200	250
Hot Coatings--Galvanizing without Fume Scrubber	700	260	600	600	100
Cold Coatings--Tin	1,200	260	1,700	1,700	425
Cold Coatings--Chrome	1,200	230	1,000	1,000	250

Source: EPA, Development Document for Iron and Steel Industry Point Source Category, Phase I and II; plus TBS calculation

Exhibit 21

RECOVERABLE BY-PRODUCTS FROM WATER POLLUTION CONTROL TREATMENT*

Process	Pollution Control Level	By-Product(s)	Quantity/Ton of Primary Process Output	Price/Unit of Recoverable (1972 $)
1. Ore Yard	BASE BPCTCA BATEA			
2. Coal Yard	BASE BPCTCA BATEA			
3. Scrap Yard	BASE BPCTCA BATEA			
4. Sinter Strand	BASE	Sinterable fines	75-100 lbs.	$4/ton
	BPCTCA BATEA	No Additional Recoveries		
5. By Product Coking	BASE	Ammonia	1-2 lbs.	n.a.
		Sodium Phenolate (as Phenol)	.5 lbs.	n.a.
		Tar Acids (crude)	7-17 gals.	n.a.
		Light Oils (crude)	3-6 gals.	n.a.
		Pyridine (crude)	.02 gals.	n.a.
		Napthalene	2-3 lbs.	n.a.
	BPCTCA	Ammonia	1-2 lbs.	n.a.
	BATEA	No Additional Recoveries		
6. Direct Reduction Unit	BASE BPCTCA BATEA			
7. Blast Furnace	BASE	Sinterable iron oxide	130-350 lbs.	$14/ton
	BPCTCA BATEA	No Significant Recoveries		
8. Open Hearth Furnace	BASE	Sinterable Iron Oxides	10-50 lbs.	$10/ton
		Steam**	1000-1200 lbs.	-
	BPCTCA BATEA	No Recoverable Iron Oxides		
9. Basic Oxygen Furnace	BASE	Sinterable Iron Oxides	10-50 lbs.	$10/ton
		Steam▲	250-300 lbs.	-
	BPCTCA BATEA	No Recoverable Iron Oxides		
10. Electric Furnace	BASE	Sinterable Iron Oxides	10-50 lbs.	$10/ton
	BPCTCA BATEA	No Recoverable Iron Oxides		
11. Conventional Casting Unit	BASE BPCTCA BATEA			
12. Continuous Casting Billet Unit	BASE BPCTCA BATEA	No Recoveries Practiced		
13. Continuous Casting Slab Unit	BASE BPCTCA BATEA	No Recoveries Practiced		
14. Hot Forming Primary - Blooms	BASE			
	BPCTCA	Dirty Oil	.3 lbs. (.04 gals)	$.02-05/gal.
		Fine Scale	n.a.	0▲▲
	BATEA	Fine Scale	n.a.	0
15. Hot Forming Primary - Billets	BASE			
	BPCTCA	Dirty Oil	.3 lbs. (.04 gals)	$.02-.05/gal.
		Fine Scale	n.a.	0▲▲
	BATEA	Fine Scale	n.a.	0
16. Hot Forming Primary - Slabs	BASE			
	BPCTCA	Dirty Oil	.3 lbs. (.04 gals)	$.02-.05/gal.
		Fine Scale	n.a.	0▲▲
	BATEA	Fine Scale	n.a.	0

(continued)

Exhibit 21
Page 2 of 2

Process	Pollution Control Level	Byproduct(s)	Quantity/Ton of Primary Process Output	Price/Unit of Recoverable (1972 $)
17. Heavy Structurals	BASE BPCTCA BATEA	●		
18. Hot Rolled Bar and Rod	BASE BPCTCA BATEA	●		
19. Wire Products	BASE BPCTCA BATEA	●		
20. Cold Finished Bars	BASE BPCTCA BATEA	●		
21. Seamless Pipe and Tube	BASE BPCTCA BATEA			
22. Hot Rolled Strip	BASE BPCTCA BATEA	Dirty Oil	5 lbs.	$.02-.05/gal.
23. Pickling and Oiling: Continuous Hydrochloric●●	BASE BPCTCA	16-20% HCl	20 gals. (if 37% HCl is used in the primary process.)	$25.75/ton (223 gal. of acid/ton)
	BATEA	Sinterable Oxide	35-40 lbs.	$14.00/ton
Pickling and Oiling: Continuous Sulphuric	BASE BPCTCA BATEA	14-17% H_2SO_4 Ferrous Sulfate Heptahydrate	15-20 gals. (if 98% H_2SO_4 is used in the primary process.) 70-80 lbs.	$ 2.30/ton (219 gal. of acid/ton) $ 0-10/ton■
24. Welded Pipe and Tube	BASE BPCTCA BATEA			
25. Cold Rolled Strip	BASE BPCTCA BATEA	Oils		0
26. Hot Coating - Galvanizing	BASE BPCTCA BATEA			
27. Cold Coating - Tin and Chrome	BASE BPCTCA BATEA	Chromium	.5-1.5 lbs.	n.a.
28. Plate	BASE BPCTCA BATEA	Dirty Oil	3.5 lbs.	$02.-05/gal.
29. Ancillary Facilities	BASE BPCTCA BATEA			

* This does not include by-products attributable to production.

** Only those open hearths equipped with superheater waste heat boilers run at 650°F can generate this by-product.

▲ Only those basic oxygen furnaces equipped with waste heat boilers can generate this by-product.

▲▲ Fine scale has no value except as landfill.

● Processes 17-20 are agglomerated as "Hot Forming Section" in the NUS/Cyrus Rice Division study. The corresponding recoverable by-products for this process are:

BASE BPCTCA BATEA	Dirty Oil	4 lbs.	$.01-.04/gal.

●● This data is a valid estimate for only those facilities which treat concentrates and rinses separately rather than combined.

■ Price is function of both location and demand.

n.a.= not available

Source: NUS/Rice engineering data

Exhibit 22

EFFLUENT GUIDELINES BASE WATER TREATMENT COSTS

(1972 dollars per ton)

SUBCATEGORY	CAPITAL COST	OPERATING COST	TOTAL LABOR AND MAINTENANCE	SLUDGE DISPOSAL	TOTAL ENERGY	CHEMICALS	OTHER
By-Product Coke--Alternate I	4.802	0.247	0.168	0.015	0.062	0.002	0
By-Product Coke--Alternate II	4.802	0.247	0.168	0.015	0.062	0.002	0
Sintering	0.524	0.033	0.018	0	0.015	0	0
Blast Furnace	1.754	0.243	0.061	0.085	0.046	0.051	0
Open Hearth Furnace	0.344	0.034	0.012	0.016	0.006	0	0
Basic Oxygen Furnace--Wet	0.491	0.084	0.017	0.052	0.015	0	0
Basic Oxygen Furnace-Semi-Wet	0.312	0.047	0.011	0	0.008	0.028	0
Electric Furnace--Wet	0.773	0.068	0.027	0.018	0.023	0	0
Electric Furnace--Semi-Wet	0	0	0	0	0	0	0
Vacuum Degassing	1.424	0.05	0.050	0	0	0	0
Continuous Casting	0	0	0	0	0	0	0
Hot Forming--Primary	0.164	0.006	0.006	0	0	0	0
Hot Forming--Section	0.657	0.023	0.023	0	0	0	0
Hot Forming--Hot Strip and Sheet	0.236	0.008	0.008	0	0	0	0
Hot Forming--Plate	0.527	0.018	0.018	0	0	0	0
Pipe and Tubes--Integrated, Seamless and Other	1.502	0.063	0.053	0.010	0	0	0
Pipe and Tubes--Integrated, Welded	1.502	0.063	0.053	0.010	0	0	0
Pipe and Tubes--Isolated, Seamless or Welded	1.502	0.063	0.053	0.010	0	0	0
Pickling--H_2SO_4 Batch Concentrates and Rinses	0.572	1.332	0.020	1.283	0.029	0	0
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization	1.786	1.437	0.064	1.283	0.076	0.014	0
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery	0.584	1.329	0.020	1.283	0.026	0	0
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I)	0.762	1.083	0.027	0	0.012	0.018	1.026
Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	0.739	1.088	0.026	0	0.018	0.018	1.026
Cold Rolling--Combination	0.531	0.062	0.019	0.034	0.009	0	0
Cold Rolling--Recirculation	0.184	0	0.006	0.002	0.001	0	0
Cold Rolling--Direct Application	1.065	0.132	0.037	0.077	0.018	0	0
Hot Coatings--Terne	1.065	0	0	0	0	0	0
Hot Coatings--Galvanizing	0	0	0	0	0	0	0
Cold Coatings--Tin	0	0	0	0	0	0	0
Cold Coatings--Chrome	0	0	0	0	0	0	0

Source: EPA, Development Document for Iron and Steel Industry
Point Source Category, Phase I and II; plus TBS calculation

Exhibit 23

EFFLUENT GUIDELINES BPCTCA WATER TREATMENT COSTS

(1972 dollars per ton)

SUBCATEGORY	CAPITAL COST	OPERATING COST	TOTAL LABOR AND MAINTENANCE	SLUDGE DISPOSAL	TOTAL ENERGY	CHEMICALS	OTHER
By-Product Coke--Alternate I	0.180	0.136	0.006	0.015	0.066	0.049	0
By-Product Coke--Alternate II	0.496	0.210	0.017	0.015	0.105	0.073	0
Sintering	0.244	0.021	0.009	0	0.009	0.003	0
Blast Furnace	1.275	0.080	0.045	0	0.035	0	0
Open Hearth Furnace	0.205	0.029	0.007	0	0.006	0.016	0
Basic Oxygen Furnace--Wet	0.174	0.062	0.006	0	0.006	0.050	0
Basic Oxygen Furnace-Semi-Wet	0.110	0.008	0.004	0	0.004	0	0
Electric Furnace--Wet	0.348	0.031	0.012	0	0.012	0.007	0
Electric Furnace--Semi-Wet	1.070	0.090	0.037	0.013	0.037	0.003	0
Vacuum Degassing	2.323	0.204	0.081	0	0	0.123	0
Continuous Casting	5.276	0.308	0.185	0.002	0.121	0	0
Hot Forming--Primary	1.244	0.108	0.044	0.009	0.055	0	0
Hot Forming--Section	5.194	0.352	0.182	0.027	0.143	0	0
Hot Forming--Hot Strip and Sheet	4.758	0.456	0.167	0.040	0.249	0	0
Hot Forming--Plate	8.958	0.803	0.314	0.038	0.366	0.085	0
Pipe and Tubes--Integrated, Seamless and Other	4.634	0.372	0.162	0.029	0.181	0	0
Pipe and Tubes--Integrated, Welded	4.634	0.372	0.162	0.029	0.181	0	0
Pipe and Tubes--Isolated, Seamless or Welded	1.289	0.083	0.045	0	0.038	0	0
Pickling--H_2SO_4 Batch Concentrates and Rinses	10.044	1.137	0.352	0.123	0.662	0	0
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization	1.726	1.138	0.060	0.616	0.027	0.435	0
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery	5.127	0.712	0.179	0.123	0.410	0	0
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I)	9.473	0.395	0.332	0.006	0.027	0.030	0
Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	0.860	0.591	0.030	0.149	0.022	0.390	0
Cold Rolling--Combination	2.313	0.311	0.081	0.024	0.161	0.045	0
Cold Rolling--Recirculation	0.263	0.025	0.009	0.001	0.012	0.003	0
Cold Rolling--Direct Application	4.275	0.596	0.150	0.055	0.289	0.102	0
Hot Coatings--Terne	4.475	0.290	0.157	0.003	0.062	0.068	0
Hot Coatings--Galvanizing	4.574	0.332	0.160	0.014	0.067	0.091	0
Cold Coatings--Tin	3.525	0.351	0.123	0.007	0.082	0.139	0
Cold Coatings--Chrome	3.095	0.248	0.108	0.004	0.066	0.070	0

Source: EPA, Development Document for Iron and Steel Industry
Point Source Category, Phase I and II; plus TBS calculation

Exhibit 24

EFFLUENT GUIDELINES BATEA WATER TREATMENT COSTS
(1972 dollars per ton)

SUBCATEGORY	CAPITAL COST	OPERATING COST	TOTAL LABOR AND MAIN-TENANCE	SLUDGE DISPOSAL	TOTAL ENERGY	CHEMICALS	OTHER
By-Product Coke--Alternate I	0.715	0.488	0.025	0.002	0.049	0.149	0.263
By-Product Coke--Alternate II	0.530	0.053	0.019	0	0.029	0.005	0
Sintering	0.281	0.028	0.010	0	0.017	0.001	0
Blast Furnace	0.357	0.202	0.012	0	0.009	0.021	0.160
Open Hearth Furnace	0.604	0.034	0.021	0	0.006	0.007	0
Basic Oxygen Furnace--Wet	0.136	0.012	0.005	0	0.005	0.002	0
Basic Oxygen Furnace-Semi-Wet				SAME AS BPCTCA			
Electric Furnace--Wet	0.448	0.032	0.016	0	0.015	0.001	0
Electric Furnace--Semi-Wet				SAME AS BPCTCA			
Vacuum Degassing	1.684	0.258	0.059	0	0.195	0.004	0
Continuous Casting	0.264	0.038	0.009	0	0.029	0	0
Hot Forming--Primary	0.311	0.026	0.011	0	0.015	0	0
Hot Forming--Section	5.650	0.365	0.198	0	0.167	0	0
Hot Forming--Hot Strip and Sheet	3.803	0.251	0.133	0	0.118	0	0
Hot Forming--Plate				SAME AS BPCTCA			
Pipe and Tubes--Integrated, Seamless and Other	3.756	0.263	0.131	0	0.132	0	0
Pipe and Tubes--Integrated, Welded	0.570	0.038	0.020	0	0.018	0	0
Pipe and Tubes--Isolated, Seamless or Welded	0.570	0.038	0.020	0	0.018	0	0
Pickling--H_2SO_4 Batch Concentrates and Rinses				SAME AS BPCTCA			
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization	0.373	0.075	0.013	0	0.009	0.053	0
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery				SAME AS BPCTCA			
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I)	0.295	0.015	0.010	0	0.005	0	0
Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	0.232	0.012	0.008	0	0.004	0	0
Cold Rolling--Combination				SAME AS BPCTCA			
Cold Rolling--Recirculation				SAME AS BPCTCA			
Cold Rolling--Direct Application				SAME AS BPCTCA			
Hot Coatings--Terne	1.090	0.066	0.038	0.002	0.026	0	0
Hot Coatings--Galvanizing	1.090	0.066	0.038	0.002	0.026	0	0
Cold Coatings--Tin	1.345	0.097	0.047	0.003	0.045	0.002	0
Cold Coatings--Chrome	1.027	0.073	0.036	0.002	0.034	0.001	0

Source: EPA, Development Document for Iron and Steel Industry
Point Source Category, Phase I and II; plus TBS calculation

Exhibit 25

COMPLIANCE RATIOS: WATER POLLUTION TREATMENT FACILITIES IN PLACE
1972 and 1974
(percent of steel industry)

Subcategory	1972			1974		
	BASE	BPCTCA	BATEA	BASE	BPCTCA	BATEA
By-Product Coking--Alternate I	100.0	39.0	4.5	100.0	59.0	6.3
By-Product Coking--Alternate II	100.0	16.7	0.5	100.0	26.7	1.3
Sintering	100.0	56.0	8.0	100.0	60.0	10.0
Blast Furnace	100.0	35.0	4.0	100.0	50.0	10.0
Open Hearth Furnace	100.0	70.0	0	100.0	70.0	0
Basic Oxygen Furnace--Wet	100.0	75.0	5.0	100.0	76.0	8.0
Basic Oxygen Furnace--Semi-Wet	100.0	75.0	75.0	100.0	80.0	80.0
Electric Furnace--Wet	100.0	77.0	7.0	100.0	78.0	12.0
Electric Furnace--Semi-Wet	100.0	100.0	100.0	100.0	100.0	100.0
Vacuum Degassing	100.0	95.0	13.0	100.0	96.0	18.0
Continuous Casting	100.0	100.0	30.0	100.0	100.0	73.0
Hot Forming--Primary	100.0	16.0	4.0	100.0	18.0	4.0
Hot Forming--Section	100.0	15.0	1.0	100.0	20.0	1.0
Hot Forming--Hot Strip and Sheet	100.0	19.0	4.0	100.0	24.0	4.0
Hot Forming--Plate	100.0	8.0	8.0	100.0	8.0	8.0
Pipe and Tube--Integrated, Seamless, and Other	100.0	14.0	2.0	100.0	16.0	2.0
Pipe and Tube--Integrated, Welded	100.0	8.0	4.0	100.0	12.0	5.0
Pipe and Tube--Isolated, Seamless or Welded	100.0	20.0	6.0	100.0	20.0	8.0
Pickling--H_2SO_4 Batch Concentrates and Rinses	100.0	5.0	5.0	100.0	8.0	8.0
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization	100.0	35.0	10.0	100.0	40.0	12.0
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery	100.0	2.0	2.0	100.0	2.0	2.0
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I)	100.0	45.0	7.0	100.0	47.0	12.0
Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	100.0	5.0	0	100.0	8.0	0
Cold Rolling--Recirculation	100.0	85.0	85.0	100.0	88.0	88.0
Cold Rolling--Direct Application	100.0	65.0	65.0	100.0	70.0	70.0
Cold Rolling--Combination	100.0	40.0	40.0	100.0	40.0	40.0
Hot Coating--Galvanizing	100.0	42.0	6.0	100.0	48.0	8.0
Hot Coating--Terne	100.0	20.0	0	100.0	20.0	0
Cold Coating--Tin	100.0	28.0	10.0	100.0	35.0	15.0
Cold Coating--Chrome	100.0	12.0	0	100.0	30.0	0

Source: NUS/Rice engineering data

Exhibit 26

CAPITAL COST EQUATION PARAMETERS

Subcategory	COEFFICIENT "A"			
	BASE	BPCTCA	BATEA	NSPS
By-Product Coke--Alternate I	52.65	1.99	7.89	9.88
By-Product Coke--Alternate II	53.00	5.47	5.85	11.32
Sintering	6.06	2.82	3.25	6.07
Blast Furnace	21.10	15.34	4.29	19.64
Open Hearth Furnace	5.71	3.41	10.03	13.44
Basic Oxygen Furnace--Wet	8.25	2.93	2.29	5.22
Basic Oxygen Furnace--Semi-Wet	4.39	1.54	0	1.54
Electric Furnace--Wet	7.33	3.30	4.25	7.55
Electric Furnace--Semi-Wet	9.73	0	0	9.73
Vacuum Degassing	8.18	13.34	9.67	23.02
Continuous Casting	0	40.45	2.03	42.48
Hot Forming--Primary	1.85	14.01	3.50	17.51
Hot Forming--Section	3.93	31.10	33.83	64.92
Hot Forming--Hot Strip and Sheet	2.61	52.50	41.96	94.46
Hot Forming--Plate	3.75	63.71	0	63.71
Pipe and Tubes--Integrated, Seamless and Other	6.73	20.77	16.84	37.61
Pipe and Tubes--Integrated, Welded	6.73	20.77	2.55	23.33
Pipe and Tubes--Isolated, Seamless or Welded	6.73	5.78	2.55	8.33
Pickling--H_2SO_4 Batch Concentrates and Rinses	1.77	31.09	0	31.09
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization	12.75	12.01	2.60	14.61
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery	4.06	35.67	0	35.67
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I)	9.53	106.07	3.30	109.37
Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	8.23	9.62	2.60	12.22
Cold Rolling--Combination	4.04	17.59	0	17.59
Cold Rolling--Recirculation	2.06	2.94	0	2.94
Cold Rolling--Direct Application	5.74	23.04	0	23.04
Hot Coatings--Terne	0	20.91	5.09	26.01
Hot Coatings--Galvanizing	0	21.37	5.09	26.47
Cold Coatings--Tin	0	20.44	7.80	28.23
Cold Coatings--Chrome	0	15.87	5.27	21.14

Source: EPA, Development Document for Iron and Steel Industry Point Source Category, Phase I and II; plus TBS calculation

Exhibit 27

ENERGY REQUIREMENTS FOR WATER POLLUTION CONTROL TREATMENT

(kwh usage per ton)

Reproduced from best available copy.

Subcategory	Effluent Guideline Standards			
	BASE	BPCTCA	BATEA	NSPS
By-Product Coke--Alternate I	1.40	0.17	3.49	3.66
By-Product Coke--Alternate II	1.40	2.97	2.10	5.07
Sintering	1.05	0.61	1.22	1.83
Blast Furnace	3.32	2.53	0.61	3.14
Open Hearth Furnace	0.44	0.44	0.44	0.88
Basic Oxygen Furnace--Wet	1.05	0.44	0.35	0.79
Basic Oxygen Furnace--Semi-Wet	0.61	0.26	0.26	0.52
Electric Furnace--Wet	1.66	0.87	1.05	1.92
Electric Furnace--Semi-Wet	0	2.62	0	2.62
Vacuum Degassing	0	0	13.97	13.97
Continuous Casting	0	0	0	0
Hot Forming--Primary	0	3.93	1.05	4.98
Hot Forming--Section	0	0	0	0
Hot Forming--Hot Strip and Sheet	0	17.82	8.47	26.29
Hot Forming--Plate	0	26.20	0	26.20
Pipe and Tubes--Integrated, Seamless and Other	0	12.93	9.43	22.36
Pipe and Tubes--Integrated, Welded	0	12.93	1.31	14.24
Pipe and Tubes--Isolated, Seamless or Welded	0	2.71	1.31	4.02
Pickling--H_2SO_4 Batch Concentrates and Rinses	2.10	47.42	0	47.42
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Neutralization	5.41	1.92	0.61	2.53
Pickling--H_2SO_4 Continuous Concentrates and Rinses, Acid Recovery	1.83	29.34	0	29.34
Pickling--HCL Continuous Concentrates and Rinses, Neutralization (Alternate I)	0.87	1.92	0.35	2.27
Pickling--HCL Continuous Concentrates and Rinses, Acid Recovery (Alternate II)	1.31	1.57	0.26	1.83
Cold Rolling--Combination	0.61	11.53	0	11.53
Cold Rolling--Recirculation	0.09	0.87	0.87	1.74
Cold Rolling--Direct Application	1.31	20.70	0	20.70
Hot Coatings--Terne	0	4.45	1.83	6.28
Hot Coatings--Galvanizing	0	4.80	1.83	6.63
Cold Coatings--Tin	0	5.85	3.23	9.08
Cold Coatings--Chrome	0	4.72	2.45	7.17

Source: EPA, Development Document for Iron and Steel Industry
Point Source Category, Phase I and II; plus TBS calculation

Exhibit 28

AIR POLLUTION CONTROL TREATMENT METHODS

(percent of facilities treated with each type of equipment)

Process	1974			1978		
	Fabric Filter	Scrubber	Electro-static Precipitator	Fabric Filter	Scrubber	Electro-static Precipitator
Sinter-Strand	6.3	-	-	100.0	-	-
Sinter-Windbox	2.1	30.3	3.8	2.3	94.1	3.6
Coke Ovens	-	-	-	-	100.0	-
Open Hearth Furnace	-	9.1	70.1	-	9.2	90.8
Basic Oxygen Furnace	-	51.7	46.8	-	33.9	66.1
Electric Air Furnace	56.8	13.3	1.3	83.4	15.3	1.4

Source: 1974--Cost of Clean Air, 1974
1978--EPA/SEAS

Exhibit 29

COST PARAMETERS FOR AIR POLLUTION CONTROL CAPITAL EXPENDITURES
STACK EMISSIONS

Process	Control Equipment	Parameters	
		A	B
Sinter[1]	Fabric Filter	133.7	0.678
Coke Ovens			
Charging	n.a.	1.4	1.073
Pushing	n.a.	42.1	0.829
Desulfurization	n.a.	82.4	0.774
Open Hearth Furnace	Scrubber	339.8	0.588
	Electrostatic Precipitators	167.0	0.783
Basic Oxygen Furnace	Scrubber	0.9	1.000
	Electrostatic Precipitators	364.7	0.689
Electric Air Furnace	Fabric Filter	*	1.701
	Scrubber	*	1.600
	Electrostatic Precipitators	6.3	1.000

[1] Standard and windbox not separately estimated.

*Less than 0.05

n.a. = not available

Source: Cost of Clean Air, 1974, Appendix C.

Exhibit 30

COST PARAMETERS FOR AIR POLLUTION CONTROL OPERATIONS AND MAINTENANCE COSTS STACK EMISSIONS

Process	Control Equipment	Power		Labor		Maintenance	
		A	B	A	B	A	B
Sinter							
Strand	Fabric Filter	41.9	0.804	384.2	0.161	10.4	0.585
Windbox	Fabric Filter	7.9	0.930	223.4	0.226	0.3	0.879
	Scrubber	14.2	0.951	5.6	0.547	0.6	0.827
	Electrostatic Precipitator	3.9	1.015	223.4	0.226	0.9	0.783
Coke Ovens							
Charging	n.a.	n.a.	n.a.	n.a.	n.a.	4.0	0.834
Pushing	n.a.	n.a.	n.a.	n.a.	n.a.	0.2	1.058
Desulfurization	n.a.	n.a.	n.a.	n.a.	n.a.	20.2	0.740
Open Hearth Furnace	Scrubber	101.5	0.942	293.7	0.302	4.0	0.767
	Electrostatic Precipitator	18.3	0.953	146.9	0.302	7.8	0.691
Basic Oxygen Furnace	Scrubber	11.9	1.060	1.4	0.626	7.0	0.690
	Electrostatic Precipitator	1.9	1.136	0.7	0.626	1.2	0.817
Electric Air Furnace	Fabric Filter	117.9	0.839	186.9	0.281	34.3	0.581
	Scrubber	736.9	0.821	373.8	0.281	32.8	0.592
	Electrostatic Precipitator	1.9	1.136	0.7	0.626	1.2	0.817

n.a. = not available

Source: Environmental Protection Agency, Cost of Clean Air, 1974

Exhibit 31

COST PARAMETERS FOR AIR POLLUTION CONTROL
CAPITAL EXPENDITURES AND OPERATIONS AND MAINTENANCE
FUGITIVE EMISSIONS

(dollar values in thousands of 1975 dollars)

Process/Duct Type	Capital Expenditures	Operations and Maintenance			
		Power	Labor	Maintenance	Miscellaneous
	($)	(thousand kwh)	(manhours)	($)	($)
Sinter					
Canopy	704	877	2,835	34	7
Coke Ovens	2,965	n.a.	n.a.	n.a.	708
Blast Furnace					
Evacuation	5,020	11,693	37,800	2,440	96
Canopy	2,020	3,508	11,340	98	29
Open Hearth Furnace					
Canopy	2,246	4,034	13,046	109	33
Basic Oxygen Furnace					
Evacuation	8,539	23,386	75,600	416	191
Canopy	1,312	1,988	6,426	64	16
Electric Furnace					
Evacuation	8,539	23,386	75,600	416	191
Canopy	1,483	2,339	7,560	72	19

n.a. = not available

Source: Environmental Protection Agency

Exhibit 32

INCOME STATEMENT LOGIC

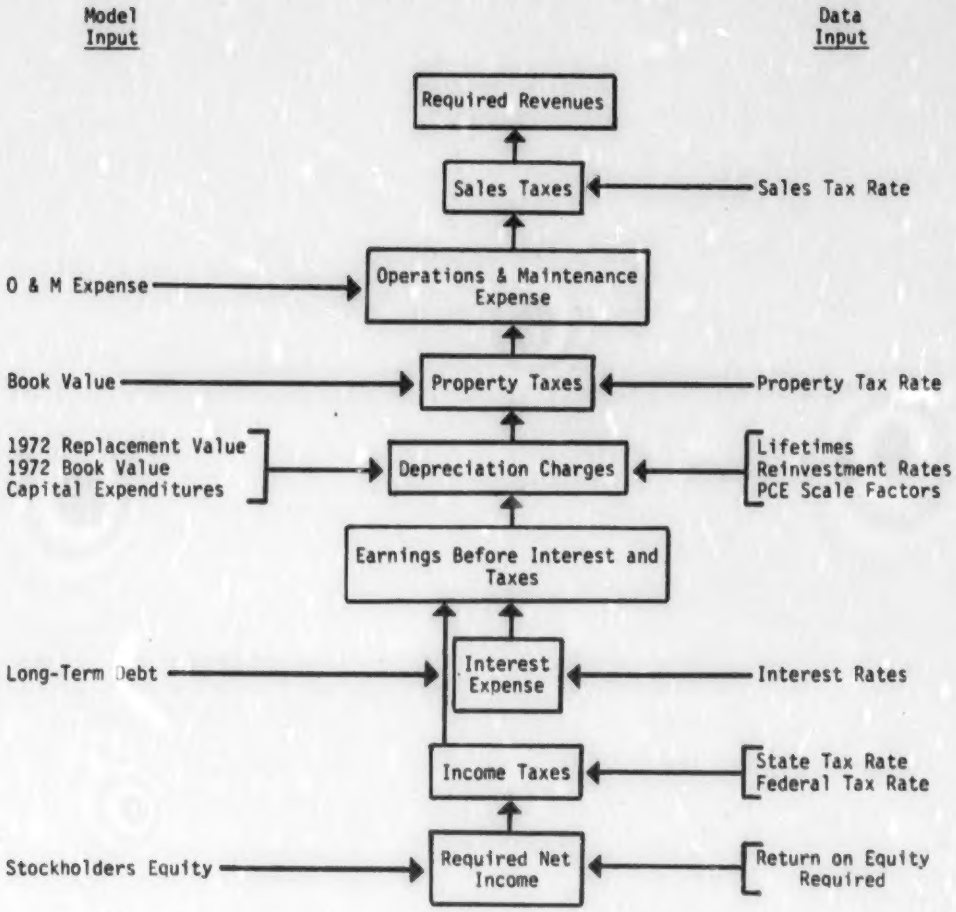
Model Input
Data Input
Required Revenues
Sales Taxes
Sales Tax Rate
O & M Expense
Operations & Maintenance Expense
Book Value
Property Taxes
Property Tax Rate
1972 Replacement Value
1972 Book Value
Capital Expenditures
Depreciation Charges
Lifetimes
Reinvestment Rates
PCE Scale Factors
Earnings Before Interest and Taxes
Long-Term Debt
Interest Expense
Interest Rates
Income Taxes
State Tax Rate
Federal Tax Rate
Stockholders Equity
Required Net Income
Return on Equity Required

Exhibit 33

FLOW OF FUNDS LOGIC

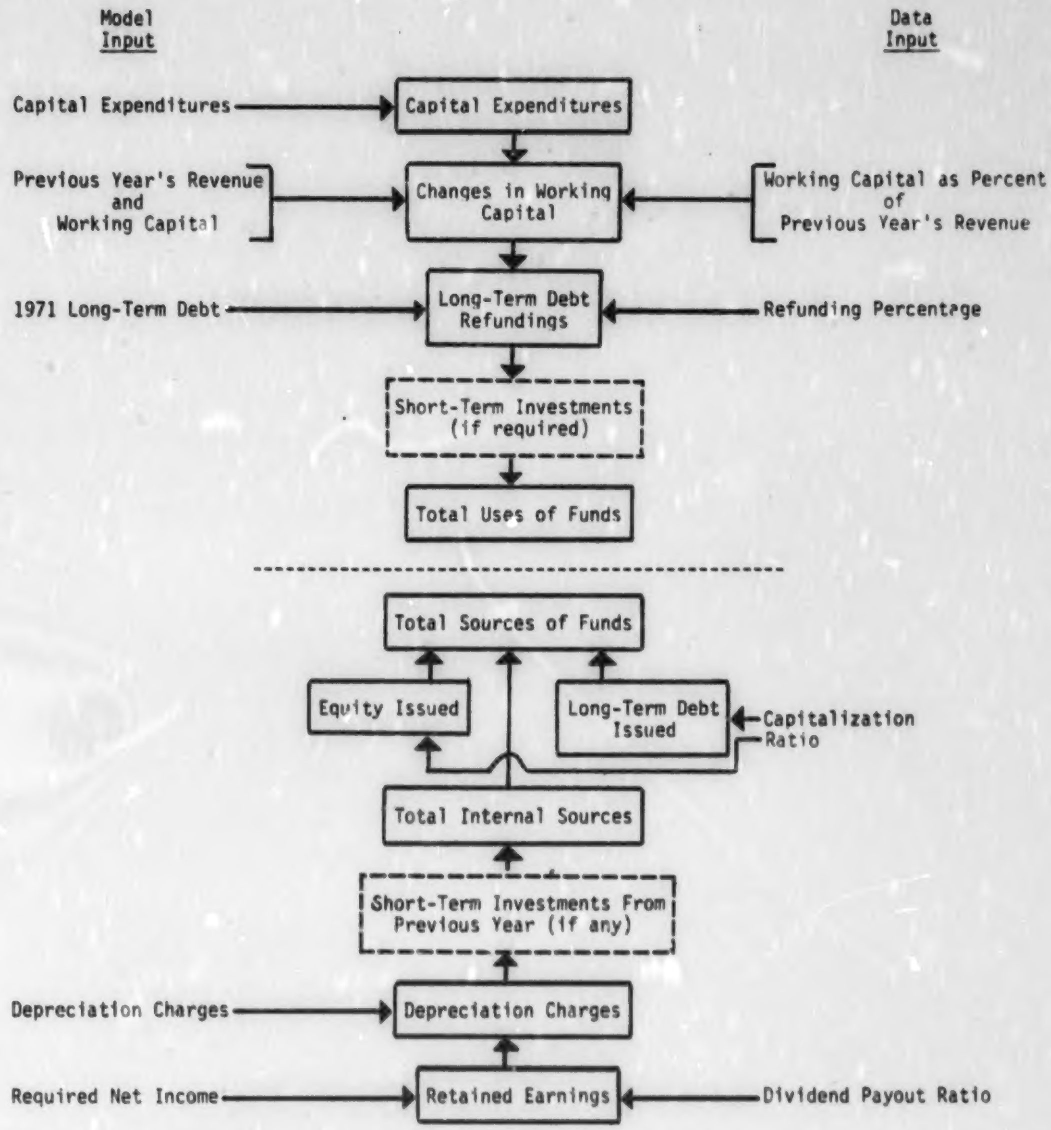
Model Input
Data Input
Capital Expenditures
Capital Expenditures
Previous Year's Revenue and Working Capital
Changes in Working Capital
Working Capital as Percent of Previous Year's Revenue
1971 Long-Term Debt
Long-Term Debt Refundings
Refunding Percentage
Short-Term Investments (if required)
Total Uses of Funds
Total Sources of Funds
Equity Issued
Long-Term Debt Issued
Capitalization Ratio
Total Internal Sources
Short-Term Investments From Previous Year (if any)
Depreciation Charges
Depreciation Charges
Required Net Income
Retained Earnings
Dividend Payout Ratio

Exhibit 34

INCOME STATEMENT

CONSTANT DOLLARS REPORT -- 1977
FNT608 02/11/76

	CURRENT $	1975 $
PRICE	34494	30266
SHIPMENTS	105071	105071
REVENUE	36243790	31800681
-OP COSTS PROD	29294774	25703541
-OP COSTS WATER	290936	255271
-OP COSTS AIR	88119	77317
-OP COSTS OTHER		
-DEPREC. PROD	468982	411490
-DEPREC. REWORKS	1109230	973250
-DEPREC. WATER	49198	43167
-DEPREC. AIR	21922	19235
-DEPREC. OTHER		
-SALES TAX	1438878	1262487
-PROPERTY TAX	373669	327862
EARNINGS BEFORE I + T	3108081	2727062
+INTEREST INCOME		
-INTEREST EXPENSE	510355	447790
EARNINGS BEFORE TAXES	2597726	2279272
-FEDERAL TAX	678006	594890
-STATE TAX	196128	172085
EARNINGS AFTER TAXES	1723591	1512297
-PREFERRED DIVIDENDS		
EARNINGS FOR COMMON	1723591	1512297
-COMMON DIVIDENDS	958317	840837
RETAINED EARNINGS	765274	671460
PROD. EMPLOYEES	399590	399590
WATER EMPLOYEES	1970	1970
AIR EMPLOYEES	407	407
OTHER EMPLOYEES		

Exhibit 35

FUNDS FLOW

	SOURCES	
DEPREC. PROD	468982	411490
DEPREC. REWORKS	1109230	973250
DEPREC. WATER	49198	43167
DEPREC. AIR	21922	19235
DEPREC. OTHER		
RETAINED EARNINGS	765274	671460
ADDITIONS TO COMMON	345842	303445
NEW LONG TERM DEBT	979403	859339
	------	------
TOTAL SOURCES	3739852	3281386
	USES	
CAPITAL EXPEND. PROD	2114353	1855156
CAPITAL EXPEND. REWORKS	1942009	1703939
CAPITAL EXPEND. WATER		
CAPITAL EXPEND. AIR		
CAPITAL EXPEND. OTHER		
CHANGE IN CWIP	-791499	-694470
CHANGE IN WORKING CAP	1023557	898080
REFUNDINGS	168054	147452
CHANGE IN INVESTMENTS	-716622	-628772
	------	------
TOTAL USES	3739852	3281386

Exhibit 36

RETURN ON EQUITY CALCULATIONS

	Actual ROE[1] (%)	Actual[2] Change in GNP Deflator (%)	Real ROE (%)		Forecast[3] Change in GNP Deflator (%)	Forecast ROE (%)
1965	9.4	1.8	7.6			
1966	8.9	2.8	6.1			
1967	6.9	3.2	3.7			
1968	8.2	4.0	4.2			
1969	7.0	4.8	2.2	Average=3.5		
1970	4.1	5.5	(1.4)			
1971	4.3	4.5	(0.2)			
1972	5.8	3.4	2.4			
1973	9.3	5.6	3.7			
1974	17.1	10.2	6.9			
1975					9.5	13.0
1976					7.1	10.6
1977					6.5	10.0
1978					5.7	9.2
1979					5.2	8.7
1980					4.8	8.3
1981					4.7	8.2
1982					4.7	8.2
1983					4.7	8.2
1984					4.8	8.3
1985					4.6	8.1

Source:
1. AISI Annual Statistical Report, 1974
2. Economic Report of the President, 1975
3. Forecasts for the EPA made by Chase Econometric Associates, Inc.

Exhibit 37

INTEREST RATE CALCULATIONS

	Actual[1] Interest Rate (Baa) (%)	Actual[2] Change in GNP Deflator (%)	Real Interest Rate (%)	Forecast[3] Change in GNP Deflator (%)	Forecast Interest Rate (%)
1965	4.9	1.8	3.1		
1966	5.7	2.8	2.9		
1967	6.2	3.2	3.0		
1968	6.9	4.0	2.9		
1969	7.8	4.8	3.0	Average≅3.0	
1970	9.1	5.5	3.6		
1971	8.6	4.5	4.1		
1972	8.2	3.4	4.8		
1973	8.2	5.6	2.6		
1974	9.5	10.2	(0.7)		
1975				9.5	12.5
1976				7.1	10.1
1977				6.5	9.5
1978				5.7	8.7
1979				5.2	8.2
1980				4.8	7.8
1981				4.7	7.7
1982				4.7	7.7
1983				4.7	7.7
1984				4.8	7.8
1985				4.6	7.6

Source:
1. Moody's Industrials Manual
2. Economic Report of the President, 1975
3. Forecasts for the EPA made by Chase Econometric Associates, Inc.

Exhibit 38

BALANCE SHEET

```
                                      ASSETS

GROSS PLANT VAL PROD            11176649
- ACCUM DEPREC. PROD             5662676
                                  ------
NET PLANT VAL PROD               5513973

GROSS PLANT VAL REWORKS         23034055
- ACCUM DEPREC. REWORKS         13495503
                                  ------
NET PLANT VAL REWORKS            9538552

GROSS PLANT VAL WATER            1184348
-ACCUM DEPREC. WATER              733775
                                  ------
NET PLANT VAL WATER               450573

GROSS PLANT VAL AIR               534240
-ACCUM DEPREC. AIR                336940
                                  ------
NET PLANT VAL AIR                 197300

GROSS PLANT VAL OTHER
-ACCUM DEPREC, OTHER
                                  ------
NET PLANT VAL OTHER

CONSTR WORK IN PROG              2264754
INVESTMENTS
WORKING CAPITAL                  6028505
MISC. ASSETS
                                  ------
TOTAL ASSETS                    23993658


                                 LIABILITIES

1971 LONG TERM DEBT              4098871
+ CUMM LONG TERM DEBT            3027834
- CUMM REFUNDINGS                1008322
                                  ------
LONG TERM DEBT                   6118383

1971 EQUITY                     10053728
+ CUMM RETAINED EARN             4950814
+ CUMM ADDITIONS                 2870734
                                  ------
EQUITY                          17875275
                                  ------
TOTAL LIABILITIES               23993658
```

APPENDIX A

STEEL DEMAND

APPENDIX A

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APPENDIX A
STEEL DEMAND

MEASURES OF DEMAND

Any analysis of steel demand, whether based on past data or projections, must be concerned with the related quantities of apparent consumption of steel, shipments of steel products and net imports. These figures measure the amount of steel mill products consumed[1] in the U.S., the amount of products actually produced by domestic steel mills, and the nation's foreign trade balance in steel mill products. If changes in producer inventories are disregarded, consumption of steel must equal the sum of steel shipments plus net imports.

The level of operations within the steel industry is directly related to shipments of steel products. For this reason, demand for steel within PTm(Steel) is expressed in terms of steel shipments. Of course, any forecast of shipments must be consistent with an overall economic scenario which includes forecasts of apparent consumption and net imports. Such consistency can be developed by independently forecasting any two of these three components.

FORECASTING METHODOLOGIES

Forecasts of the demand for steel can be developed in many different ways. For the purposes of this analysis, TBS has reviewed the forecasts of a number of different authors and used them to develop the baseline demand scenario currently used in PTm(Steel). The forecasts examined differ from each other in terms of author, methodology and underlying economic scenario.

---

[1] *"Consumption:" includes products used for changes in consumer inventories.*

Exhibit A-1 displays the relationship of these factors for each forecast. As this exhibit makes clear, each of the forecasts examined was prepared using either trend analysis, simple statistical modeling, the methodology of the International Iron & Steel Institute, or econometric modeling. These methodologies will be discussed in more detail below and specific forecasts will be explained. The alternative economic scenarios which underlie several of the forecasts will also be reviewed.

TREND ANALYSIS

Steel demand projections based on the extrapolation of past trends rely on the simplest and most common forecasting technique--that of trend analysis. Trend analysis relies on relative constancy in the movements of a variable. In this case, past steel demand trends are assumed to be a good indication of what will occur in the future.

The use of extrapolation in trend analysis prevents this methodology from identifying turning points or cycles in steel demand projections. Extrapolation also introduces the risk of continuing an increase in demand long after the basic growth process has been altered by changes in the economy. However, trend analysis is simple and inexpensive to use, and because of the unavoidable uncertainty in any forecast regardless of methodology, it is often justified through a cost/accuracy trade-off.

Trend analysis may implicitly assume linear or exponential growth by concentrating on absolute or percent changes over time. Although exponential growth best describes many processes, different percent change figures are not strictly comparable across different base years. To overcome this problem in evaluating and comparing different forecasts, TBS analyzed past data for steel consumption and shipments from 1946 to 1974 and computed the annualized percent change for each combination of base and final year. These figures were then classified by the number of years in the calculation period, and the average for each period length was computed. The resulting numbers are charted in Exhibit A-2. The data in this exhibit lend support to the commonly quoted[2] forecast of 2.5 percent growth in steel consumption in the next five to ten years. As can be seen, the growth rate in steel shipments has been less than 2 percent.

Exhibits A-3, A-4, and A-5 display forecasts of apparent consumption of steel, steel shipments, and net imports of steel presented by different authors. Three forecasts made utilizing the trend methodology are included. The first is based on linear trend lines fitted to 1960-1974 data by TBS using linear regression techniques. Linear trends were used after analysis showed that, for all three measures of steel demand, these provided a better fit with the data than did exponential trends. The slopes of the trend lines are 3.5 million tons per year for steel consumption, 2.6 million tons per year for shipments, and .9 million tons per year for net imports.

---

[2] *The 2.5 percent figure was originally developed by the AISI and has been widely quoted in the business press.*

The second set of trend forecasts presented in the exhibits are those of the American Iron and Steel Institute. Until recently, the AISI has projected steel consumption based on the previously mentioned growth rate of 2.5 percent per year. This forecast was modified in June 1975 to accommodate the continuing downturn in steel demand. New forecasts made by the AISI call for an annual consumption of 135 million tons of steel by 1983. Using the 1974 consumption figure as a base, this represents a 1.36 percent annual growth rate. The AISI forecasts for 1980 and 1985 have been calculated using this rate with 1974 as the base and are displayed in Exhibit A-3.

The AISI does not forecast shipments of steel products and net imports directly. Instead, gross imports are estimated by assuming that imports in any given year will equal 14 percent of steel consumption in that year. This percentage figure is slightly less than the average over the last five years. The gross imports figure is then converted to net imports by assuming that exports will equal 4.5 million short tons in each year. The AISI net imports projections, calculated using this procedure, are shown in Exhibit A-4. Forecasts of steel shipments, equal to projected consumption minus net imports, have been calculated and are displayed in Exhibit A-5.

The third set of forecasts which use the trend methodology are those prepared by Booz, Allen and Hamilton for the Materials, Equipment, and Construction task force of Project Independence. Projections of apparent consumption of steel were prepared by assuming a 2.5 percent yearly growth rate and taking 1970 as a base year. However, rather than use 1970 consumption, the base magnitude for projection was taken to be the average of actual steel consumption from 1969 through 1972. This figure equals 103 million tons. Consumption projections made using this methodology are shown in Exhibit A-3.

A different methodology was used by Booz, Allen and Hamilton to forecast shipments of steel products. Here interviews were held with steel company and industry officials, and individual forecasts of shipments were compiled. These numbers are listed in Exhibit A-5. The net imports forecasts attributed to Booz, Allen in Exhibit A-4 were developed by subtracting their forecasts of steel shipments from consumption in both years.

SIMPLE STATISTICAL MODELS

Simple statistical models of steel demand attempt to relate steel consumption or shipments to more basic economic variables such as gross national product and the unemployment rate. Thus the demand projections are keyed to the performance of the overall economy and not simply to past demand data. The exact relationship between demand and an underlying economic variable such as GNP is estimated using past data and is assumed to remain constant during the forecast period.

Well designed and estimated models are generally able to predict both turning points and cycles in demand if these are due to an independent variable which can be identified. In addition, such models will generally follow the cycles of the overall economy and will link the forecasted quantity with the general economic conditions at a given time. However, such models do not forecast actual structural changes in the economy, and they are not suitable for projecting a large number of interdependent variables and relationships.

The simple models being discussed rely on input forecasts of basic economic variables in order to develop output projections of steel demand. This requirement adds complexity since the uncertainty in the input forecasts generate uncertainty in the projections, compounding the basic variance in the process being modeled.

TBS has analyzed and compared two simple statistical models of steel demand. The first is a single equation model which forecasts steel consumption as a function of time, GNP, and unemployment. This equation was developed by Booz, Allen and Hamilton in their 1972 report to the Council on Environmental Quality concerning the economic impact on the steel industry of meeting federal pollution control requirements. The equation was estimated using data from 1954 to 1971.

The second model has been developed by TBS using actual data for 1947 to 1974. Equations are specified which project consumption, shipments, and net imports based on GNP, unemployment, and in the case of net imports, a dummy variable which accounts for the combination of strike threats and the willingness of foreign steel makers to sell steel products to the United States at abnormally low prices during the last 15 years. These equations and that of Booz, Allen and Hamilton are displayed in Exhibit A-6. Since the Booz, Allen equation predicts steel consumption only, net imports and steel shipments were derived from this number using the AISI methodology described previously.

In order to use these equations for forecasting steel demand it is necessary to select specific projections of real GNP and the unemployment rate to use as inputs. Two such projections have been used by TBS in order to capture some of the uncertainty regarding the future path of the economy. The first projection uses numbers for real GNP and unemployment rate provided to the Environmental Protection Agency by Chase Econometrics, Inc. from the April 1975 Chase forecast. This forecast is fairly pessimistic over the long term and projects a relatively slower growth in GNP and employment along with a brief downturn in the overall economy in 1978. The second projection is based on numbers provided by the Bureau of Labor Statistics from the BLS economic model. These numbers are relatively more optimistic over the long term and show continuous growth in both real GNP and employment through 1985. Both the Chase and BLS projections are displayed in Exhibit A-7.

The Chase and BLS forecasts have been input to both of the simple statistical models. The resulting four sets of steel demand projections are shown in Exhibits A-3 to A-5. In addition, two forecasts of shipments were developed from the TBS model for each economic scenario. The first of these was calculated directly from the regression equation for shipments, and the second was derived by subtracting the forecasted net imports from forecasted apparent consumption in each year.

INTERNATIONAL IRON AND STEEL INSTITUTE METHODOLOGY

In March 1972 the International Iron and Steel Institute published "Projection 85," a forecast of world steel demand through 1985. Demand was projected in terms of apparent consumption of raw steel for the entire world and for regions and larger producing countries. The methodology used combined time series forecasts of gross national product and populations for each area with a forecast of steel consumption per unit of GNP. The consumption/GNP forecast was developed from a cross-sectional study which related steel consumption per unit of GNP to per capita GNP and enabled the IISI to forecast steel consumption for a wide variety of economies in different stages of development.

As shown in Exhibit A-7, the IISI used particularly optimistic forecasts of United States real GNP and population in order to derive projected U.S. steel consumption. Although these numbers may have seemed realistic in 1972, they no longer appear likely. Further, the IISI recommended using a yield factor of .77 to convert its forecasts to finished steel product equivalents. This factor, which represents the yield of steel products from raw steel, is somewhat high compared to U.S. experience.

In view of these drawbacks, TBS has prepared updated versions of the IISI forecasts which utilize the more recent forecasts of GNP and population developed by Chase Econometrics, Inc. and the Bureau of Labor Statistics. In addition, each of the updated forecasts uses a yield factor of .71, a more reasonable number for the U.S. steel industry. Finally, because the IISI methodology only projects steel consumption, net imports and shipments are calculated using the AISI methodology as previously mentioned. The resulting sets of steel demand projections are displayed in Exhibits A-3, A-4, and A-5.

COMPLEX ECONOMETRIC MODELS

The final type of methodology represented in the sample of steel demand forecasts is econometric modeling. Econometric models are the most formal of those examined and represent part or all of an economy as a set of equations which can be solved for the desired economic quantities. Such models, which range in size from a few to hundreds of equations, assume continuity in the relationships and structure of an economic system.

Steel demand forecasts from Data Resources, Inc., Chase Econometrics, Inc., and the Bureau of Labor Statistics, all well-established sources using large econometric models, have been included in Exhibits A-3 to A-5. Because of the lack of detailed information about the DRI, Chase, and BLS models, it is difficult to examine the assumptions and model structure which underlie the actual forecasts. To some extent, however, the forecasts of GNP and unemployment rate produced by these models indicate their projections for the economy as a whole. Such macro-projections form a useful background when comparing specific forecasts of steel demand. Three of these are displayed in Exhibit A-7.

Some differences exist in the exact form of steel demand forecasts from each of the models. The Data Resources, Inc. forecast is expressed in physical units (tons of steel products) and is compatible with the projections derived from other methodologies. However, the steel demand projections from both the Chase Econometrics, Inc. model and the Bureau of Labor Statistics model are expressed as the total real value of steel shipments in 1971 dollars. In order to convert these forecasts to physical units, the 1973 product mix was assumed to be valid throughout the forecast period. The forecast values were then indexed using the 1973 actual value (in 1971 dollars) as the base, and physical unit forecasts were calculated by multiplying the index number times 1973 actual shipments in tons.

REVIEW OF STEEL DEMAND FORECASTS

Exhibits A-8, A-9, and A-10 display each of the steel demand forecasts and show both the relationship of individual forecasts to one another and the variation in the entire group of forecasts. The following discussion will examine, in turn, forecasts of consumption, net imports, and shipments.

STEEL CONSUMPTION

Exhibit A-8 displays forecasts of 1980 steel consumption varying from 117 to 153 million short tons. There is a slight concentration of forecasts around the lower numbers, but in general the projections are evenly spread over the entire range. Eight of the eleven forecasts fall below the linear trend reference point, suggesting a general decrease in the growth rate of consumption from that experienced in recent years.

Forecasts which use the BLS economic projections as input are found high in the range along with the BLS and DRI steel forecasts. Projections which use the more pessimistic Chase numbers are low in the range. This separation underlines the overwhelming effect of the overall economic conditions, as measured by real GNP and unemployment, on steel demand.

Much of the variation in forecasts can be attributed to different assumptions, either implicit or explicit, about the timing and vigor of the economy's recovery and growth.

As might be expected, forecasts of 1985 steel consumption span a considerably larger range than the 1980 projections. 1985 consumption forecasts vary from 134 to 188 million short tons, with a concentration of forecasts below 160 million short tons. Once again most of the forecasts fall below the linear trend reference point. The overwhelming effect of different GNP and unemployment rate projections is clear in 1985 as well as 1980.

Forecasts made using the trend and IISI methodologies show less variation. In 1980, the trend forecasts made by the AISI and by Booz, Allen and Hamilton for Project Independence are close to each other and located slightly below the middle of the range. The IISI forecasts are slightly more separated and located relatively low in the range. In 1985 both trend and IISI forecasts are separated further and are found in the bottom half of the range.

NET IMPORTS

Net imports of steel is the most difficult measure of demand to forecast since this measure is directly affected not only by domestic economic developments but by foreign ones as well. The 1980 net imports forecasts are evenly spread across a span from 12 to 22 million short tons. The 1985 forecasts divide roughly into two groups, one ranging from 13 to 18 million short tons and one ranging from 22 to 25 million short tons. In addition, the TBS/BLS forecast for 1985 is approximately 29 million short tons.

The effect of different GNP and unemployment rate projections is again clear, with forecasts driven by the relatively optimistic BLS numbers found at the upper end of the scale and those relying on the Chase numbers being lower. The trend forecasts and those made using IISI methodology are grouped at the lower end of the range in both years. Almost all of the forecasts fall below the linear trend reference point in both 1980 and 1985.

SHIPMENTS OF STEEL PRODUCTS

Forecasts of steel shipments are of primary importance to this analysis and are used as a direct input to PTm(Steel). In general, shipments projections are quite similar to projections of consumption when considering the effects of different GNP and unemployment forecasts and when grouping forecasts produced with similar methodologies. Nine of the 13 shipments forecasts for 1980 are below the linear trend reference point; in 1985 only eight are below this point. Once again the forecasts which rely on BLS projections are relatively high compared to those that use Chase Econometrics numbers.

Forecasts for 1980 steel shipments range from 99 to 138 million short tons, with most of the projections found in a narrower band between 107 and 123 million short tons. In 1985 a similar grouping occurs at the lower end of the range, while forecasts in total vary from 120 to 166 million short tons. Several of the shipment forecasts (marked with asterisks) have been developed from projections of steel consumption by using the AISI methodology. These numbers would increase if a smaller figure was assumed for gross imports as a percent of total consumption during these years.

As previously mentioned, there are two sets of projections attributed to TBS/BLS and TBS/Chase. For each, direct shipments forecasts are listed as well as forecasts derived by subtracting projected net imports from projected consumption of steel. Both the actual and derived projections of steel shipments are within 2 percent of one another.

CONCLUSION

The projected demand for steel has been examined using a variety of measures of demand, forecasting methodologies, and underlying economic forecasts. Because the operations of the steel industry are dependent upon the level of shipments, this measure of demand is input to PTm(Steel). The baseline forecast of steel shipments for this project was developed using the linear trend in shipments from 1960-1974 developed by TBS.

EXHIBIT A-1

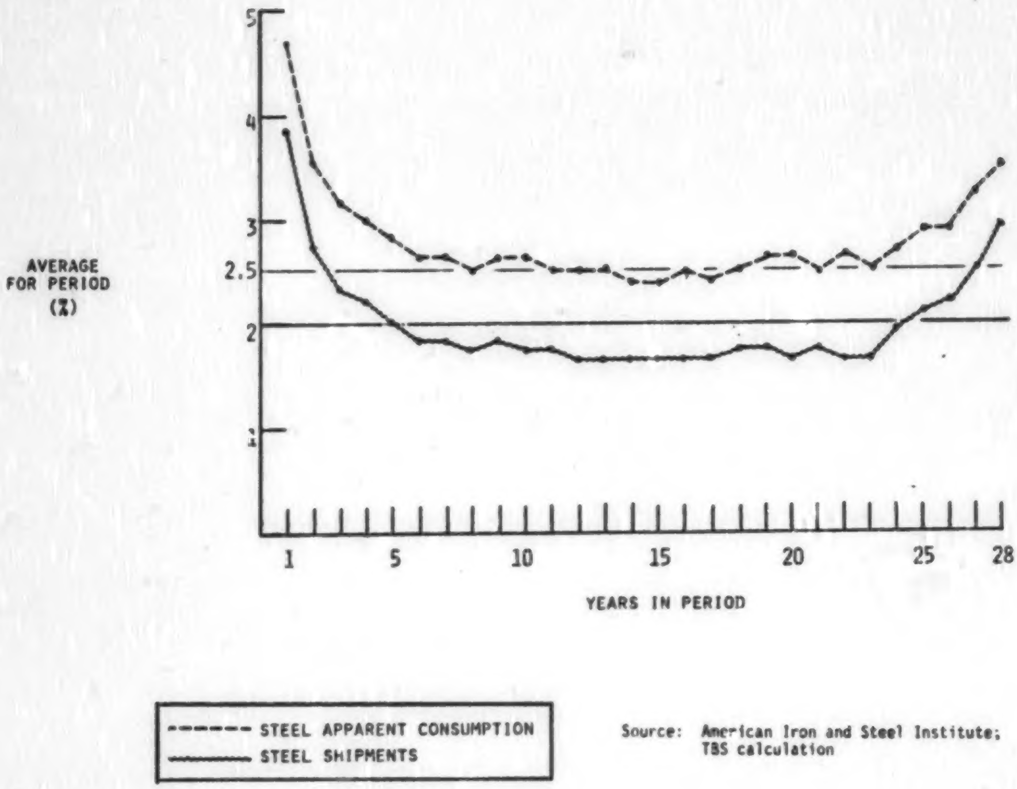
RELATIONSHIPS OF DIFFERENT FORECASTS

Methodology	Author	Economic Scenario	Forecast Label
Trend Analysis	Temple, Barker & Sloane		Trend
	American Iron & Steel Inst.		A.I.S.I.
	Booz, Allen & Hamilton/ Project Independence		B.A.H./P.I.
International Iron & Steel Inst.		International Iron & Steel Inst.	I.I.S.I.
		Chase Econometrics, Inc	I.I.S.I./Chase
		Bureau of Labor Statistics	I.I.S.I./B.L.S.
Simple Statistical Models	Booz, Allen & Hamilton/ Council on Env. Quality	Chase Econometrics, Inc.	BAH/CEQ/Chase
		Bureau of Labor Statistics	BAH/CEQ/BLS
	Temple, Barker & Sloane	Chase Econometrics, Inc.	TBS/Chase
		Bureau of Labor Statistics	TBS/BLS
Econometric Models	Chase Econometrics, Inc.		Chase
	Data Resources, Inc.		D.R.I.
	Bureau of Labor Statistics		B.L.S.

EXHIBIT A-2

AVERAGE GROWTH RATES FOR PERIODS OF DIFFERENT LENGTH

DATA FOR 1946 - 1974



Source: American Iron and Steel Institute;
TBS calculation

Exhibit A-3

STEEL APPARENT CONSUMPTION--FORECASTS
(million tons)

	1980	1985
Trend Analysis		
Linear Trend: 1960-1974	104.4	157.8
AISI (6/75)	129.7	138.8
BAH/PI	132.0	149.0
Simple Statistical Models		
BAH/CEQ/BLS	153.0	187.6
BAH/CEQ/Chase	118.7	159.7
TBS/BLS	144.0	170.3
TBS/Chase	117.0	152.3
International Iron & Steel Institute Methodology		
Original	144.5	161.6
IISI/Chase	121.4	133.8
IISI/BLS	125.0	139.9
Econometric Models		
Chase Econometrics, Inc.	125.0	136.0
Data Resources, Inc.	152.3	187.6
Bureau of Labor Statistics	137.4	142.0

Exhibit A-4

NET IMPORTS OF STEEL--FORECASTS
(million tons)

	1980	1985
Trend Analysis		
Linear Trend: 1960-1974	19.9	24.6
AISI	13.7	14.9
BAH/PI	12.0	13.0
Simple Statistical Models		
BAH/CEQ/BLS	16.9	21.8
BAH/CEQ/Chase	12.1	17.9
TBS/BLS	22.0	29.5
TBS/Chase	17.7	25.5
International Iron & Steel Institute Methodology		
Original	15.7	18.1
IISI/Chase	12.4	14.2
IISI/BLS	13.0	15.1
Econometric Models		
Chase Econometrics, Inc.	13.0	16.0
Data Resources, Inc.	15.1	24.0
Bureau of Labor Statistics	14.7	15.4

Exhibit A-5

STEEL SHIPMENTS--FORECASTS

(million tons)

	1980	1985
Trend Analysis		
Linear Trend: 1960-1974	120.6	133.3
AISI	116.0	123.9
BAH/FI	120.0	136.0
Simple Statistical Models		
BAH/CEQ/BLS	136.1	165.8
BAH/CEQ/Chase	106.6	141.8
TBS/BLS	120.3	138.6
TBS/Chase	98.6	125.0
TBS/BLS Derived	122.0	140.8
TBS/Chase Derived	99.3	126.8
International Iron & Steel Institute Methodology		
Original	128.8	143.5
IISI/Chase	108.6	119.6
IISI/BLS	112.0	124.8
Econometric Models		
Chase Econometrics, Inc.	112.2	120.2
Data Resources, Inc.	138.1	163.5
Bureau of Labor Statistics	122.7	126.6

Exhibit A-6

SIMPLE STATISTICAL MODEL EQUATIONS

Booz, Allen & Hamilton/Council on Environmental Quality:

Consumption = 13.2 - 2.56 Time + .221 Gross National Product - 2.42 Unemployment Rate

R^2* = 97.02%

SEE** = 2.4

Equation estimated with data from 1954 to 1971. However, T = 1 in 1947.

Temple, Barker & Sloane, Inc.:

Consumption = 41 .81 + .113 Gross National Product - 4.169 Unemployment Rate

R^2 = 91.5%

SEE = 5.59

Net Imports = -16.76 + .036 Gross National Product + 3.646 D_2

R^2 = 89.6%

SEE = 2.11

D_2 = 1 in 1959, 1962, 1965, 1968, 1971
= 0 in all other years

Shipments = 58.21 + .075 Gross National Product - 3.999 Unemployment Rate

R^2 = 80.3%

SEE = 6.13

All equations estimated with data from 1947 to 1974.

*R^2 is the correlation coefficient

**SEE is the standard error of the estimate

Exhibit A-7

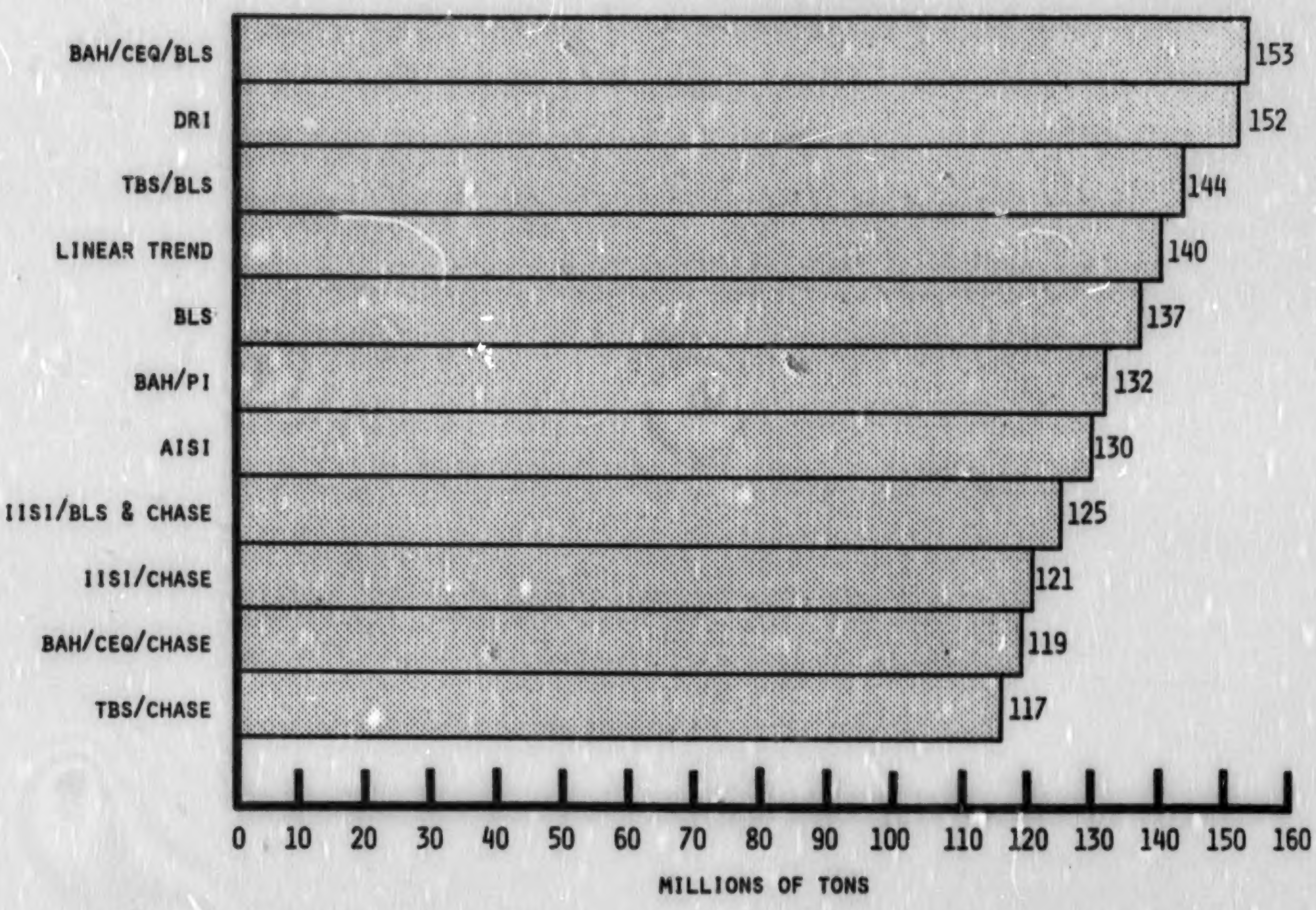
COMPARISONS OF BASIC ECONOMIC PROJECTIONS

	1975	1977	1980	1983	1985
Chase Econometrics, Inc.					
Real GNP (billions of 58$)	791.8	883.5	958.8	1100.3	1172.9
Unemployment Rate	8.95	7.28	8.0	5.94	5.3
Population (millions)	213.9	217.7	224.1	231.0	235.7
Bureau of Labor Statistics					
Real GNP (billions of 58$)	803.8	912.8	1078.0	1202.2	1284.5
Unemployment Rate	8.9	6.8	4.7	4.2	4.0
Population (millions)	213.9	217.7	224.1	231.0	235.7
International Iron & Steel Institute					
Real GNP (billions of 58$)	946.2	-	1151.4	-	1399.6
Unemployment Rate			NA		
Population (millions)	219.4	-	235.2	-	252.9

EXHIBIT A-8

CONSUMPTION FORECASTS

1980

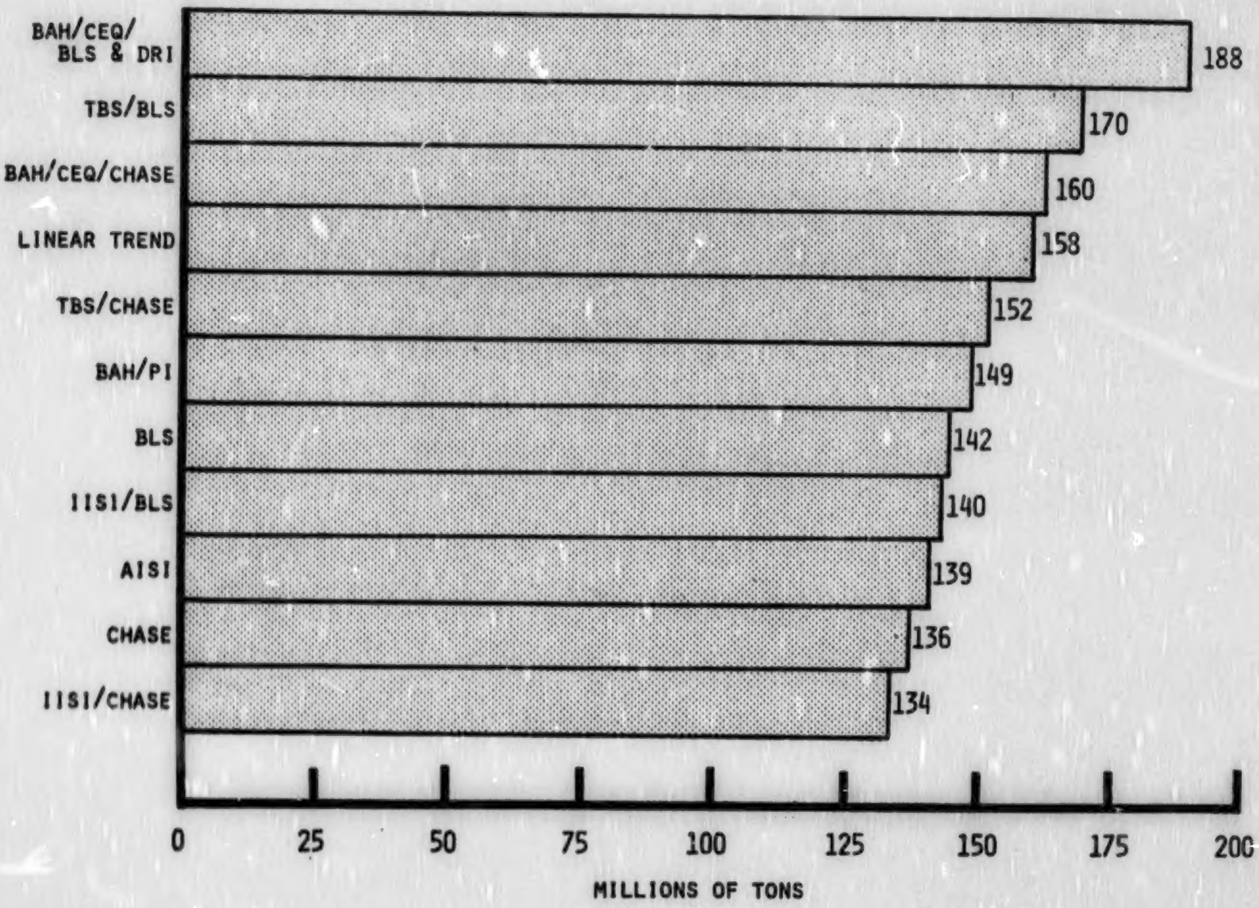


*SEE EXHIBIT A-1 FOR KEY ABBREVIATIONS

EXHIBIT A-9

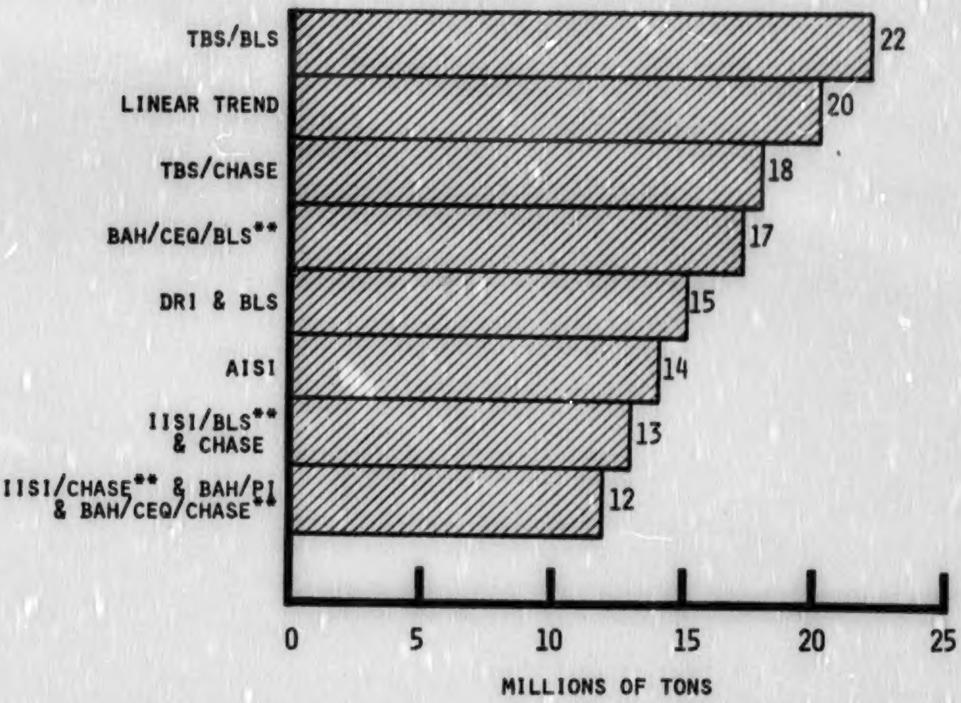
CONSUMPTION FORECASTS

1985



*SEE EXHIBIT A-1 FOR KEY ABBREVIATIONS

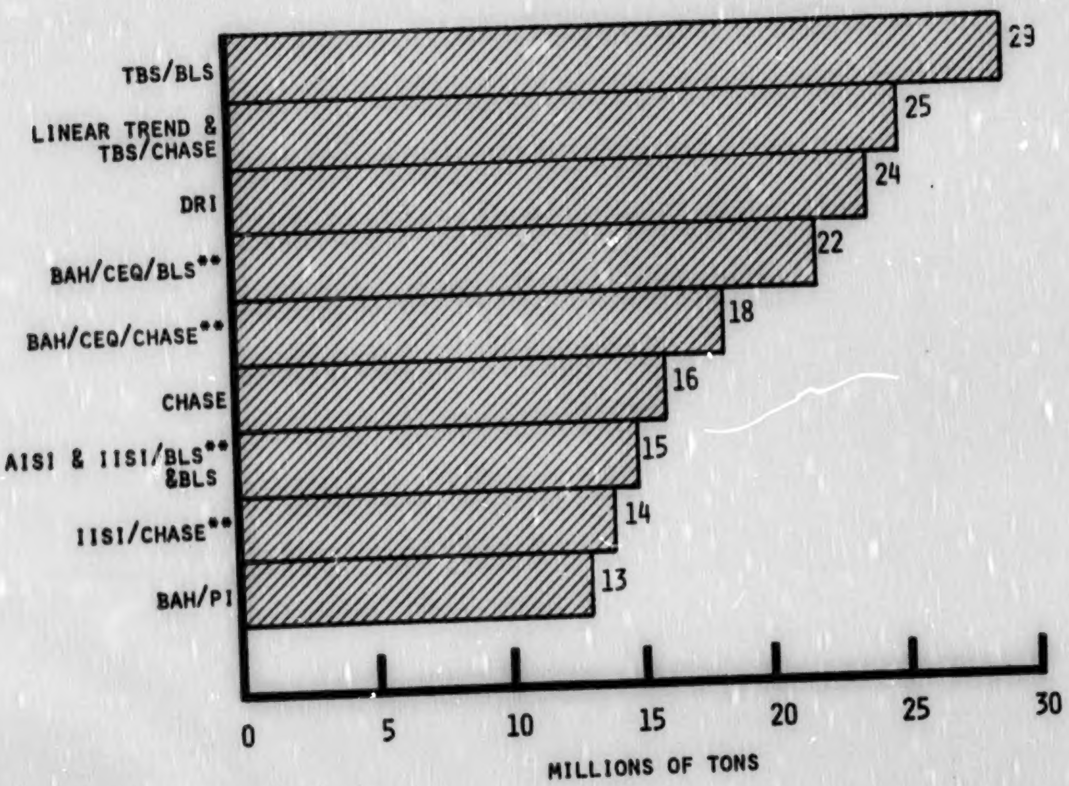
EXHIBIT A-10
NET IMPORTS FORECASTS
1980



*SEE EXHIBIT A-1 FOR KEY ABBREVIATIONS

**DERIVED FROM CONSUMPTION FORECAST USING AISI METHODOLOGY

EXHIBIT A-11
NET IMPORTS FORECASTS
1985



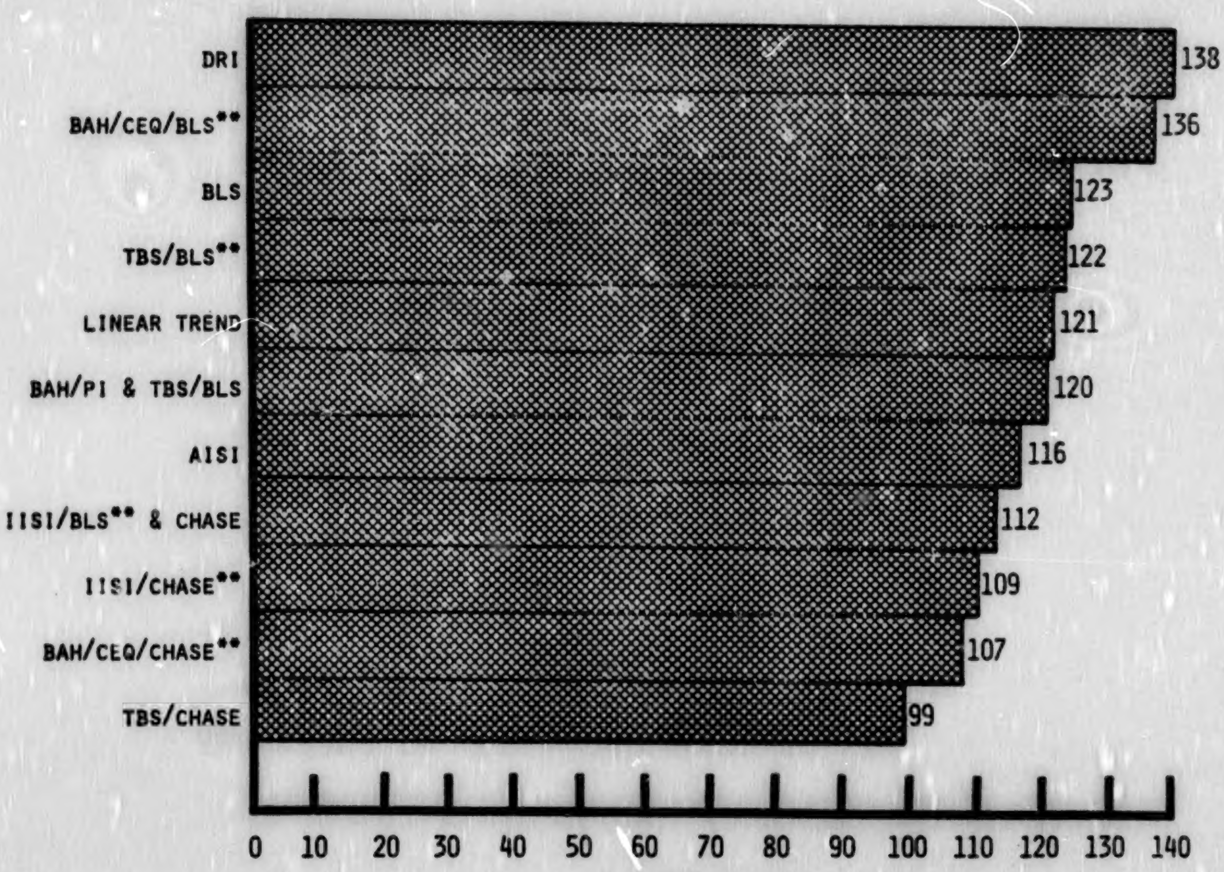
*SEE EXHIBIT A-1 FOR KEY ABBREVIATIONS

**DERIVED FROM CONSUMPTION FORECAST USING AISI METHODOLOGY

Exhibit A-12

SHIPMENTS FORECASTS

1980



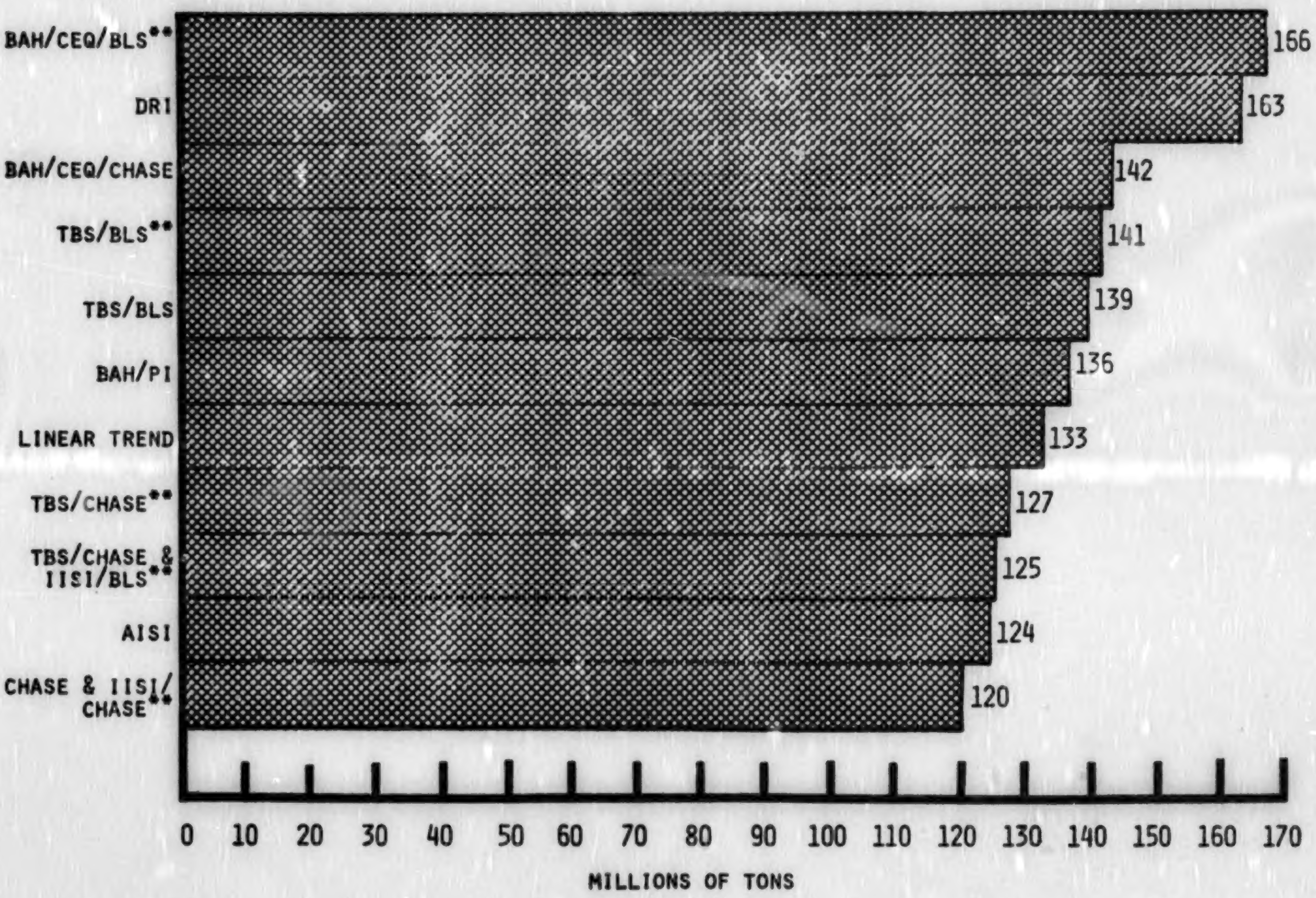
MILLIONS OF TONS

*SEE EXHIBIT A-1 FOR KEY ABBREVIATIONS

**DERIVED FROM CONSUMPTION FORECAST USING AISI METHODOLOGY

EXHIBIT A-13

SHIPMENTS FORECASTS
1985



*SEE EXHIBIT A-1 FOR KEY ABBREVIATIONS

**DERIVED FROM CONSUMPTION FORECAST USING AISI METHODOLOGY

APPENDIX B

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DEPRECIATION B-4

APPENDIX B

REINVESTMENT RATES AND DEPRECIATION CALCULATIONS

REINVESTMENT RATES

The equipment and facilities in the steel industry require expenditures from time to time for partial replacement, modernization, and maintenance. Such expenditures, which do not normally result in a net increase in capacity, are usually capitalized and written off over the normal depreciation lifetime for production equipment. "Reinvestments" or "reworks" are terms commonly used to describe these expenditures.

The basic approach used to model reinvestments in PTm(Steel) is similar to that proposed by Arthur D. Little, Inc. This method is described in some detail on pages A-11 to A-26 of the ADL report.[1] To summarize this discussion, ADL plotted the book values reported for each process unit in the 33 steel plants that they surveyed, and found a residual book value for plants older than the depreciation lifetime of 18 years. Because all of the initial investment in those process units already had been written off, the residual book values were attributed to reinvestments in the facilities. The residual values generally ranged from 5 to 15 percent of the 1972 replacement value[2] of the facilities. ADL defined an average annual reinvestment rate to account for the residual book value.

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[1] *Steel and the Environment: A Cost Impact Analysis*, *Arthur D. Little, Inc., 1975. The total future expenditures for required reinvestments reported by ADL on pages I-8 and I-9 of their report do not seem to be derived from the methodology described on pp. A11 to A16 and A22 to A26.*

[2] *1972 Replacement Value as defined by ADL is the sum of all investments for new facilities inflated to 1972 dollars using the Chemical Engineering Index.*

Equation A-9 in the ADL report expresses the ratio of book value to replacement value as a function of the reinvestment rate, the depreciation lifetime used, and the rate of inflation. ADL assumed an 18-year depreciation lifetime, an instantaneous rate of inflation of 4 percent[1] per year and used the actual ratios of book value to replacement value for the process units in the 33 plants surveyed to calculate reinvestment rates for almost all of the 29 production processes. For the few processes with insufficient data, ADL used in-house data and similarities with other processes to arrive at a reinvestment rate. The reinvestment rates as calculated express the reinvestment in a process unit in each year as a percentage of the unit's initial value. The resulting reinvestment figures are expressed in the dollars of the year of the initial investment in the unit and must be inflated or deflated to other bases.

TBS used Equation A-9 on Page A-24 of the ADL report, along with the capacity profile data supplied by ADL to compute the reinvestment rates for almost all of the 28 steelmaking and finishing processes. These computations begin with Equation A-9 from the ADL report:

$$\frac{B(T)}{I_R(T)} = \frac{1}{e^{R_I T}} \left[e^{R_I T} \left(1 - \frac{R_D}{R_I}\right) + \frac{R_D}{R_I} \, e^{R_I \left(T - \frac{1}{R_D}\right)} \right] \qquad (A\text{-}9)$$

where $B(T)$ = *calculated book value in year t after construction of facility*

$I_R(T)$ = *replacement cost in year t after construction of facility*

F = *annual reinvestment rate as a fraction of investment*

R_I = *instantaneous rate of inflation*

R_D = *reciprocal of depreciation period in years*

T = *time in years after construction of facility*

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[1] *An instantaneous rate is continuously compounded. The 4 percent rate was used only to recalculate the values supplied by ADL.*

This equation is valid for facilities which are older than the depreciation lifetime and thus, have their initial investment fully depreciated. To begin, the $e^{R_I T}$ term may be factored out of the equation and cancelled, yielding:

$$\frac{B(T)}{I_R(T)} = \frac{F}{R_I}\left[(1-\frac{R_D}{R_I}) + \frac{R_D}{R_I}\, e^{\frac{-R_I}{R_D}}\right]$$

Now because the depreciation lifetime is 18 years, R_D can be set to 1/18 or .0556. The instantaneous inflation rate can be set equal to .04 as implied on Page A-25 of the ADL report. With these substitutions, the equation becomes:

$$\frac{B(T)}{I_R(T)} = \frac{F}{.04}\left[(1-\frac{.0556}{.04}) + \frac{.0556}{.04}\, e^{-\frac{.04}{.0556}}\right]$$

$$\frac{B(T)}{I_R(T)} = 7.175\ F$$

$$\text{or } F = .139\left(\frac{B(T)}{I_R(T)}\right)$$

The reinvestment rate, or F, for each process can now be calculated by using the book value and the replacement value for pre-1954 facilities as reported by ADL in its capacity profile. For example, the 1972 book value of all the blast furnace units installed prior to 1955 is $911.43 million, and the 1972 replacement value of these facilities is $8,463.96 million. Thus, the blast furnace reinvestment rate can be calculated as:

$$F = .139\left(\frac{911.43}{8463.96}\right) = .015$$

For those processes with no pre-1954 facilities; namely the basic oxygen furnaces and continuous casting mills, reinvestment rates were obtained directly from ADL.

DEPRECIATION

In general, to calculate the series of depreciation charges resulting from an investment, one must know the amount of the investment and the year that this expenditure is made, the lifetime of the investment to be used for depreciation purposes, and the specific method to be used to calculate the depreciation charges. With regard to the latter two requirements, PTm(Steel) follows industry practice and uses the straight-line method of calculating depreciation and lifetimes of 18 years for production equipment and 14.5 years for pollution control equipment.

Depreciation charges for production facilities and pollution control equipment installed after 1972 are easily calculated by PTm(Steel) since the model determines these additions and thus has full knowledge of their timing and the magnitude of the required expenditures. Similarly, depreciation flows for the pollution control equipment already in place in 1972 are calculated easily because the magnitude of these investments is known from the pollution control cost module and the timing of the investments is publicly available. However, production facilities already in place in 1972 create more difficulties because data concerning the timing of these investments are not available.

In order to calculate the depreciation flows attributable to production equipment in place in 1972, PTm(Steel) uses an algorithm of moderate sophistication. This algorithm calculates the total depreciation flow in each future year as the sum of three parts, the depreciation flow attributable to:

1. Equipment installed before 1955: Reinvestments

2. Equipment installed after 1954: Reinvestments
3. Equipment installed after 1954: Initial Investments

Each of these steps will be explained below.

EQUIPMENT INSTALLED BEFORE 1955

All of the facilities grouped in the pre-1955 classification are older than 18 years, and so the initial investment in these facilities is fully depreciated by the end of 1972. Thus, the only depreciation charges resulting from these facilities are the result of reinvestments during the period from 1955 to 1972. Using the reinvestment rates explained previously and the 1972 replacement value for this equipment, it is possible to calculate the dollar reinvestment in the pre-1955 facilities for each process for each year from 1955 to 1972. These calculations also require knowledge of the method by which ADL inflated the initial investment in each process to arrive at the 1972 replacement value. This is explained on pages A11 to A13 of the ADL report. After calculating the dollar reinvestment in each year, the depreciation charges attributable to these expenditures are calculated easily.

In order to provide an example of these calculations, we again use the blast furnace. We know from the data supplied by ADL that the 1972 replacement value of all blast furnaces installed prior to 1955 is $8,460.0 million, and we have calculated the blast furnaces annual reinvestment rate equal to .015 of the initial investment. To calculate the dollar reinvestment in each year from 1955 to 1972, we would ordinarily need to deflate the 1972 replacement value of each process unit to the amount initially invested in this unit, multiply this by the reinvestment rate, and then inflate the resulting dollar reinvestment to the dollars of the year in which the reinvestment is occurring. This calculation would require more data concerning dates of installation than is available. However, since the same inflation factors are used for both replacement value and reinvestment calculations, it is not necessary to deflate the 1972 replacement value to the value of the initial investment. Rather, we can simply deflate the 1972 replacement value to the dollars of the year in which the reinvestment is occurring, multiply this deflated replacement value by the reinvestment rate, and get as the product the dollar reinvestment required in the current dollars.

The 1960 dollar reinvestment in blast furnaces installed before 1955 would be calculated as follows. From pages A-11 to A-13 of the ADL report, we know that the factor $e^{R_I T}$ was used to inflate initial investments to the 1972 replacement value, where R_I is the instantaneous rate of inflation and equals .04 and T is time in years after installation of the unit. In order to deflate the 1972 value to 1960 dollars, we divide by this factor. The difference in years between 1972 and the year of interest is used as T.

$$\frac{8464.0}{e^{.04(12)}} = \frac{8464.0}{1.7} = 4978.8 \text{ million dollars}$$

When multiplied by the reinvestment rate of .015, $4,978.8 yields the 1960 dollar reinvestment in blast furnaces of $74.7 million. This reinvestment creates a depreciation charge of $4.3 million each year for the years from 1961 to 1978. Similar calculations are performed by PTm(Steel) for each steel industry process for each of the years from 1955 to 1972.

EQUIPMENT INSTALLED AFTER 1955: REINVESTMENTS

Facilities installed during the period from 1955 to 1972 present a more difficult problem, because these facilities have depreciation charges attributable to both their initial investment and subsequent reinvestment in the facilities. The exact timing of installation for these facilities is unknown, and although it is possible to calculate an average rate for most processes using equation A-8 on page A-24 of the ADL report, use of these ages in the depreciation calculations results in excessive portions of depreciation being allocated to the early years of the analysis. This result is due to the unrealistic assumption that all facilities were installed in the same year and thus prevents the use of average ages in the final depreciation calculations.

A uniform investment in new facilities during the years from 1955 to 1972 is the most consistent assumption in view of capital expenditures data published by the American Iron and Steel Institute.[3] Using this assumption PTm(Steel) computes a uniform series of gross plant investments for 18 years prior to 1972 from the 1972 replacement value for post-1954 facilities reported by ADL. Reinvestments are calculated for each year based on the reinvestment rate for the process and the cumulative investment in the equipment. This part of the process is similar to the method of calculation used for pre-1955 facilities, and results in a stream of depreciation charges and a 1972 book value due only to reinvestments.

Using the blast furnace as the example, the 1972 replacement value of units installed between 1955 and 1972 is $710.0 million. By assuming a uniform series of additions during this period, we know that in 1960, 6/18 of the period total had been installed. Thus the 1960 replacement value of the blast furnaces installed between 1955 and 1960 would equal:

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[3] *Steel Industry Economics and Federal Income Tax Policy*, AISI, June 1975

$$\frac{6}{18}\left[\frac{710.0}{e^{.04(12)}}\right] = .33\left[\frac{710.0}{1.7}\right] = 137.8 \text{ million dollars}$$

When multiplied by the reinvestment rate of .015, \$137.8 million yields the 1960 dollar reinvestment in post-1954 blast furnaces of \$2.1 million. This reinvestment results in an annual depreciation charge of \$.1 million for the years from 1961 to 1978. In 1972 the book value remaining from this reinvestment is \$.9 million because it has been depreciated for 12 years.

EQUIPMENT INSTALLED AFTER 1954: INITIAL INVESTMENT

The 1972 book value attributable to reinvestments alone is subtracted from the total 1972 book value for the post-1954 facilities provided by ADL. The resulting number is the book value remaining from the initial investment. This book value for each process is converted to a stream of initial investments covering the period using the uniform investment assumption. The depreciation streams for each of those initial investments are then calculated.

For example, using the data provided for the blast furnace, we can see that the total 1972 book value for units installed after 1954 is \$306.7 million. The calculations above showed that approximately \$.9 million of this book value is attributable to reinvestments in 1960. When similar calculations are done for the entire period from 1955 to 1972, the total 1972 book value attributable to reworks is calculated to be \$56.2 million. This leaves \$250.5 million of the 1972 book value attributable to the initial investment in new blast furnaces during the period.

The 1972 book value of the initial investments can be used to calculate the investment in each year using the uniform investments assumption. Before this is done, however, PTm(Steel) scales the book value of initial investments in order to better match AISI data concerning the book value of fixed assets in the steel operations portion of the industry. The book value attributable to both pre- and post-1954 reinvestments are also scaled, but this operation does not affect the depreciation calculations in these two cases. After scaling, the initial investment portion of the book value of post-1954 blast furnace units is $184.1 million.

To calculate the investment in new blast furnaces in each year from 1955 to 1972, PTm(Steel) first calculates the amount of the 1972 book value which is attributable to each year's investment. Because the depreciation lifetime is 18 years, investments made in 1955 still have one depreciation charge remaining in the 1972 book value, investments made in 1956 have two depreciation charges remaining in the 1972 book value, etc. The sum of these remaining depreciation charges is the 1972 book value due to initial investments. This can be expressed algebraically as follows:

$$1D_1 + 2D_2 + 3D_3 + \dots + 18D_{18} = \text{1972 Book Value (initial investments)}$$

$$\text{or} \quad \sum_{i=1}^{18} iD_i = \text{1972 Book Value (initial investments)}$$

when D_i = annual depreciation charge for the investment made in $i=1$ in 1955

Now because a uniform stream of investments is assumed, the amount invested in each year will be equal and thus the annual depreciation charges (D_i) for investments made in different years will be equal. We can now remove the D_i term from under the summation:

$$D\sum_{1}^{18} i = 1972 \text{ Book Value (initial investments)}$$

and because

$$\sum_{1}^{18} i = 1 + 2 + 3 + 4 + \ldots + 18 = 171$$

we have

$$171\ (D) = 1972 \text{ Book Value (initial investments)}$$

$$\text{or } D = \frac{1972 \text{ Book Value}}{171} \text{ (initial investments)}$$

Having calculated D, the annual depreciation charge due to the investment in each year from 1955 to 1972, we can easily compute the amount of the annual investment.

$$\text{Since } D = \frac{I}{18} \text{ where } I \text{ is the investment}$$

$$\frac{I}{18} = \frac{1972 \text{ Book Value}}{171}$$

$$I = \frac{18}{171} \text{ (1972 Book Value)}$$

For the blast furnace, the annual investment in new facilities for the period would be calculated as follows:

$$I = \frac{18}{171}\ (184.1)$$

$$= .1\ (184.1)$$

$$= 18.41 \text{ million dollars}$$

The depreciation charge resulting from this investment could equal $1.0 million and would be charged each year for 18 years after the year of the initial investment.